COURSE IN
PHARMACEUTICAL ARITHMETIC

J. W. STURMER

SECOND EDITION

CORRECTIONS.

On page 13, the 5th line of Table A should read:

    10 Dekagrammes = 1 Hectogramme (Hgm. or Hg.)

Then, 10 Hectogrammes = 1 Kilogramme (Kgm. or Kg.) etc.

On page 25, the last line in the prescription should be:

    Syrupi q. s. ad f ℨ vi

On page 39, under Approximate Equivalents, the 3d line should read:

    1 f ℨ = 30 c.c.

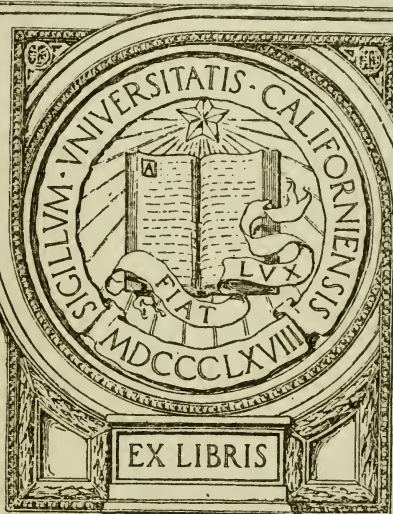On page 51, the temperature in line 2 should be 25°, and lines 6 and

7 should be $\dfrac{25°\ C}{25°\ C}$ to conform to the new U. S. P.

On page 142, the approximate atomic weight for Molybdenum should be 95.
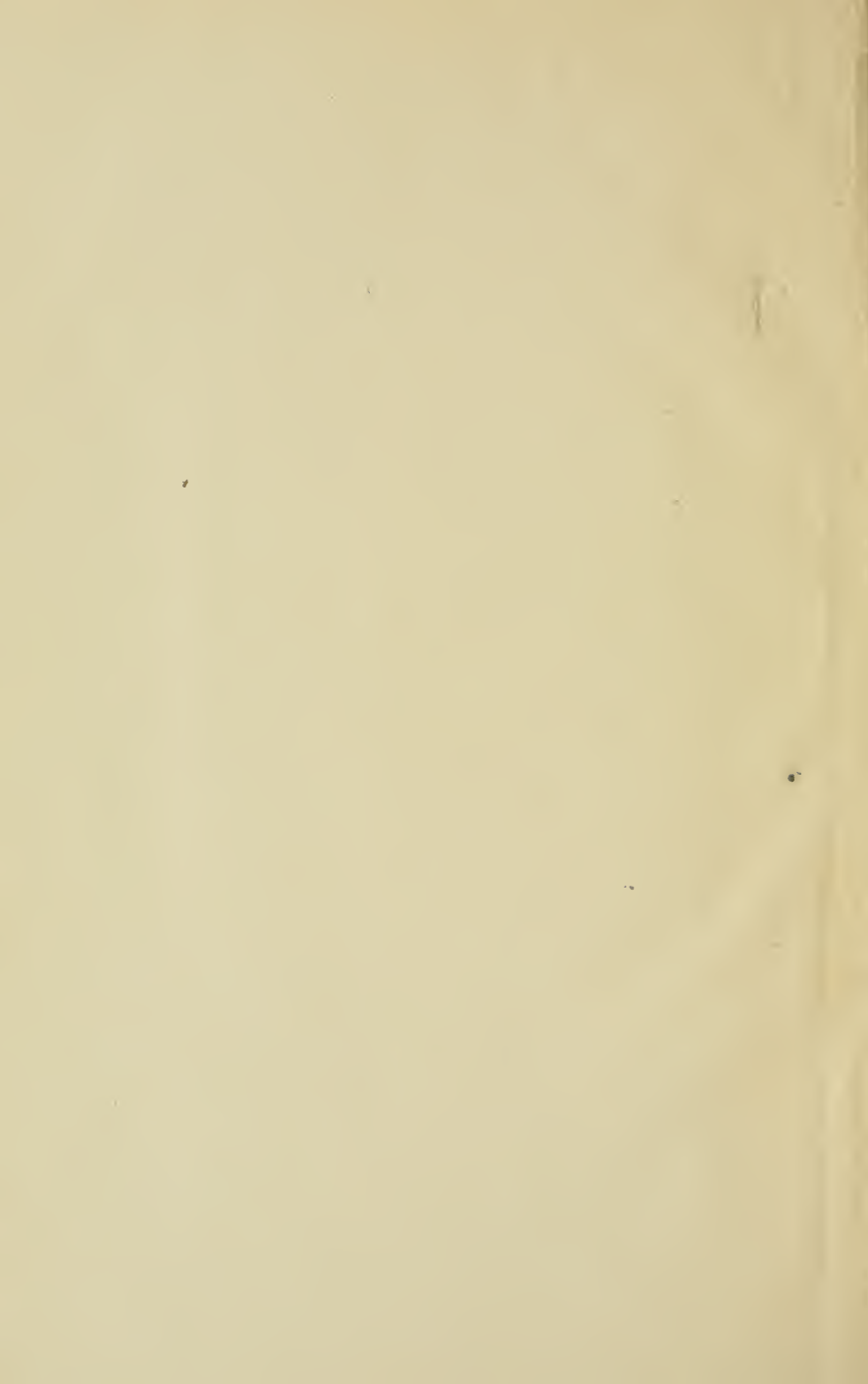
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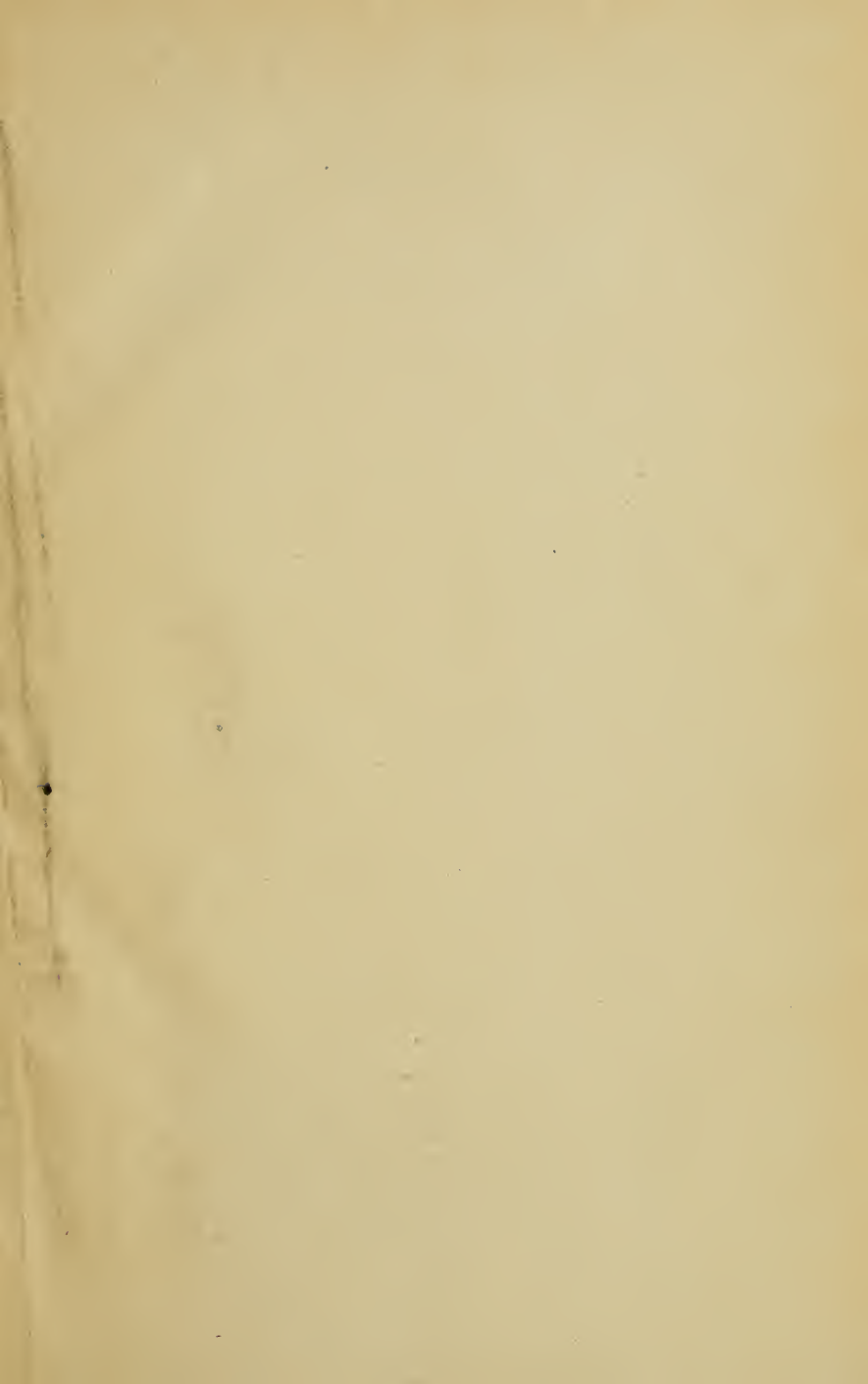
INCLUDING

WEIGHTS AND MEASURES

BY

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SECOND EDITION

With Answers

Gift of Helen Boleem

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JULIUS WILLIAM STURMER.

PREFACE TO THE SECOND EDITION.

The first edition of this little volume was so well received that the writer has decided to make no radical changes in the arrangement and scope of the Course.

As in the first edition, so also in this, the primary object is not to present rules by which the different chemical and pharmaceutical problems may be solved; but rather to enable the student to become independent of rules and mathematical formulas.

At the suggestion of members of state boards of pharmacy, a drill in vulgar and decimal fractions, for the benefit of those "who have been out of school a long while," has been embodied in chapters I and II. But the writer would advise that students who do not require such a review, be excused from this elementary work, lest they lose interest in the subject. For the same reason he would also advise the use of approximate equivalents, and round numbers, in most of the class work.

In this edition answers are given for the majority of the problems, which no doubt will enhance the value of the book to those students who study at home, and without the aid of a teacher.

<div align="right">J. W. STURMER.</div>

Purdue University, LaFayette, Ind.
        October, 1904.

PREFACE TO THE FIRST EDITION.

In this little volume the writer offers a course in Pharmaceutical arithmetic adapted to the requirements of students and pharmacists whose mathematical education has been limited (has not included algebra), but who, nevertheless, desire to master the problems which come up in pharmaceutical practice.

The subjects have been arranged in logical sequence, thus forming a **Course;** the student is therefore advised to take up the chapters in their order, omitting only such matter as he is thoroughly familiar with.

It has been the writer's aim to make all explanations and deductions in language so simple that the student working without the aid of an instructor should meet with no serious difficulties.

The problems in percentage, in fortification and dilution, as well as the chemical problems, are solved by proportion, the principles of this branch of arithmetic having been expounded at some length. In this way a multitude of rules and formulas are rendered superfluous.

Since there appears to be much confusion in regard to the meaning of percentage in prescription work, this subject has received special attention, and weight-percentage, volume-percentage, and weight-to-volume-solutions have been discussed in detail.

The problems in Chapter I are intended primarily to familiarize the student with the values of the units of weights and measures.

Acknowledgement is due to the Office of Weights and Measures, U. S. Treasury Department, and to O. Oldberg, whose manual on Weights and Measures was freely consulted.

<div align="right">

J. W. STURMER.

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Purdue University, LaFayette, Ind.

CONTENTS.

CHAPTER I.

WEIGHTS AND MEASURES.

A.—The Metric System.

The most important feature of the metric system is that the units of each of its branches are in decimal progression. Ten of any unit make one of the next higher, ten of which in turn make one of a still higher value; etc. The system thus is in conformity with our arithmetical notation; and denominate numbers in metric units can be added, subtracted, multiplied, and divided as readily as abstract numbers. In this lies the chief practical advantage of the metric system over the other systems in vogue.

The branches of the metric system are: (1)linear measure, (2) surface measure, (3) cubic measure(dry measure), (4) cubic measure for liquids (volume measure), (5) and weight.

The relationship between these branches is a very simple one—a fact constituting the second great advantage of this system of weights and measures. The primary unit of linear measure—the *Meter*—is the basis of the entire system. Thus, the primary unit of surface measure, called *Are,* is the square of ten Meters. The primary unit of cubic measure (dry), the *Stere,* is the cube of one Meter. The primary unit of volume measure, the *Liter,* is the cube of one-tenth of a Meter. And the primary unit of weight, the *Gramme,* is the weight of a cubic $\frac{1}{100}$ Meter* of water, at its greatest density, and weighed in vacuo.

For convenience in measuring, secondary units, some

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*Their relationship has been slightly altered by inaccuracy in the weighings made when the first metric weight was constructed. See page 12.

larger, and some smaller than the units already referred to,
were established. These secondary units, as has been stated,
differ from each other by ten or by some power of ten. The
names for the secondary units are formed by joining certain
Greek and Latin prefixes—Greek for multiples, Latin for
the fractionals—to the name of the unit itself.

The prefixes used are:

Latin $\left\{ \begin{array}{l} \text{milli} = \text{thousandth } (\frac{1}{1000}) \\ \text{centi} = \text{hundredth } (\frac{1}{100}) \\ \text{deci} = \text{tenth } (\frac{1}{10}) \end{array} \right.$

Greek $\left\{ \begin{array}{l} \text{Deka} = \text{ten } (10) \\ \text{Hecto} = \text{hundred } (100) \\ \text{Kilo} = \text{thousand } (1000) \\ \text{Myria} = \text{ten-thousand} (10000). \end{array} \right.$

Thus we have *milli*meter, *milli*liter, *milli*gramme; *centi*-
meter, *centi*liter, *centi*gramme; etc.

Rules for capitalizing names of units.—The names of
the primary units—Meter, [Are, Stere], Liter, Gramme—
are usually written with a capital, as are also the names of
the secondary units larger than the primary ones; but the
names of the units smaller than the primary units are writ-
ten with a small initial letter. Examples: *Deka*meter, but
*deci*meter; *Myria*gramme, but *milli*gramme. These rules,
as will be seen, serve to decrease the similarity in appearance
between the names of certain multiples and certain fraction-
als. However, the rules are not universally observed, and
in many scientific works the names of all units are written
with small initial letters.

Abbreviations.—The abbreviations for primary units
are: Meter = M; Liter = L; Gramme = Gm.

The abbreviations for the prefixes are:—milli = m;
centi = c; deci = d; Deka = D; Hecto = H; Kilo = K;
Myria = M.

To construct the abbreviation of any secondary unit,

the abbreviation of the prefix is coupled with the abbrevia-
tion for the primary unit. Thus Kilometer = Km.; milli-
meter = mm; milliliter = ml.; centigramme = cgm.; etc.

However, in case of abbreviations of secondary units of
weight the final *m* is frequently omitted. See table on page
13.

The rules given for capitalizing names of units
apply likewise to their abbreviations; Dm. being used for
Dekameter, dm. for decimeter, Mgm. for Myriagramme,
and mgm. for milligramme. But in the U. S. Pharmacopœia,
all abbreviations of metric units are capitalized; millimeter
= Mm., centimeter = Cm., milligramme = Mgm. In
ordinary practice this might lead to confusion. In the
Pharmacopœia, however, it cannot, simply because the mul-
tiples of the primary units are not in use in its text. The
abbreviation Mm. for instance, must here stand for milli-
meter, for the Myriameter is non-existent as far as the
Pharmacopœia is concerned.

1. LINEAR MEASURE.

The primary unit of length, the Meter, may be defined
as the $\frac{1}{40,000,000}$ of the earth's circumference, measured
across the poles. The distance from the equator to the
north pole was calculated from surveys made along the
meridian which passes through Paris; and this distance, di-
vided by 10,000,000, was chosen as the unit of length.*

Note.—It is deemed desirable that a system of measure be
based upon some unalterable object in nature, in order that the
correctness of the measures accepted as models may be re-
determined, should this become necessary. The metric system
is based upon the dimensions of the earth—an object ill adapted
for a "natural standard;" firstly because the earth is not abso-
lutely unalterable in size, and secondly because of the difficulty
of obtaining its measurement. A far better "natural standard"
is the second's pendulum, upon the length of which the English
measure is now based. See page 22.

[1]According to recent measurements the earth's quadrant measures 10,000,880
Meters, showing that a slight error had been made in the original measurements,
and that the unit now in use is a trifle shorter than the meter required by theory.

Table of Linear Measure.

Table A.

10 millimeters (mm.) = 1 centimeter (cm.)
10 centimeters = 1 decimeter (dm.)
10 decimeters = 1 Meter (M.)
10 Meters = 1 Dekameter (Dm.)
10 Dekameters = 1 Hectometer (Hm.)
10 Hectometers = 1 Kilometer (Km.)
10 Kilometers = 1 Myriameter (Mm.)

For miscroscopic measurements the micro-millimeter, which is $\frac{1}{1000}$ of a millimeter, is used. It is usually written micron or mikron, and abbreviated mkm.

Table B.

Kilometer	Hectometers	Dekameters	Meters	decimeters	centimeters	millimeters
1 =	10 =	100 =	1000 =	10000 =	100000 =	1000000
	1 =	10 =	100 =	1000 =	10000 =	100000
		1 =	10 =	100 =	1000 =	10000
			1 =	10 =	100 =	1000
				1 =	10 =	100
					1 =	10

Units in Common Use.—Units larger than the Meter are seldom employed in pharmaceutical literature. As has been stated on page 9, the U. S. Pharmacopœia ignores the larger units, and in its text mm. and cm. are capitalized without danger of ambiguity.

2. SURFACE MEASURE.

3. CUBIC MEASURE FOR SOLIDS. [DRY MEASURE.]

These two branches of the metric system are not used in pharmacy; hence are here omitted.

4. CUBIC MEASURE FOR FLUIDS. [VOLUME MEASURE.]

For a primary unit of volume the cube of $\frac{1}{10}$ Meter was

selected, and was named Liter. [pronounced Leeter, not Laiter].*

Tables of Volume Measure.

Table A.

10 milliliters (ml.) = 1 centiliter (cl.)
10 centiliters = 1 deciliter (dl.)
10 deciliters = 1 Liter (L.)
10 Liters = 1 Dekaliter (Dl.)
10 Dekaliters = 1 Hectoliter (Hl.)
10 Hectoliters = 1 Kiloliter (Kl.)
10 Kiloliters = 1 Myrialiter (Ml.)

The milliliter is commonly called cubic centimeter, to which it bears the same relation that the Liter bears to the cubic decimeter. The abbreviation for cubic centimeter is c.c., c.cm., or, as in the Pharmacopœia, Cc.

Table B.

Myrialiter	Kiloliters	Hectoliters	Dekaliters	Liters	deciliters	centiliters	milliliters
1 =	10 =	100 =	1000 =	10000 =	100000 =	1000000 =	10000000
	1 =	10 =	100 =	1000 =	10000 =	100000 =	1000000
		1 =	10 =	100 =	1000 =	10000 =	100000
			1 =	10 =	100 =	1000 =	10000
				1 =	10 =	100 =	1000
					1 =	10 =	100
						1 =	10

Units in Use.—In pharmaceutical and chemical works only two units are commonly used: the Liter, and the milliliter, which latter, however, is almost invariably called the

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*Weight in a vacuum is called *true weight*, in contradistinction to *apparent* the more refined methods of weighing and measuring of recent investigators have brought to light the fact that the Liter in actual use is about .06 per cent. smaller than the Liter required by theory; or, in other words, the *actual* Liter equals about .9994 + of a cubic decimeter. This difference is commonly ignored.

cubic centimeter. The table of volume measure, as actually used is therefore very simple ; namely

1000 cubic centimeters (milliliters) = 1 Liter.

However, in books and periodicals the other units are *sometimes* met with, and therefore should not be overlooked by the student.

5. WEIGHT.

The primary unit of weight, the Gramme, is defined as the weight *in vacuo** of one cubic centimeter of water, at its greatest density (4°C.). †

In pharmacy the name of the primary unit of weight is always spelled according to French orthography—*Gramme.* The English spelling, *gram,* gives to the word too great a similarity to the word grain—the name of a unit of weight of the Apothecaries' System of Weight. The pronunciation is *gram,* the *a* having the same sound as in Sam. The abbreviation is always capitalized, *Gm.,* lest it be mistaken for *gr.,* which is the abbreviation for grain.

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*Weight in a vacuum is called *true weight*, in contradistinction to *apparent weight*, which is weight obtained in air, i. e., under ordinary conditions.

Air, like water, though in a lesser degree, exerts a buoyant force on bodies; tending to lift or float both the body being weighed and the weights used. This buoyant force is exerted on a body in proportion to its bulk. Hence, if there is a difference in bulk between the body weighed and the weights used, there will be a corresponding difference in this buoyant force, and the weight obtained will not be truly proportional to mass.

It follows also that this difference in buoyant force will fluctuate with the density of the air, i. e., with the barometric pressure. For this reason the barometer reading is taken into consideration in weighings where great accuracy is required, and weighing in vacuo is impracticable. See page 31.

†Recent determination of the weight of water under standard conditions, and with the most delicate balances, have shown that the original Kilogramme weight, which has served as the model for over 100 years, is about .58 Grammes too light to represent the weight of 1 cubic decimeter of water. The primary unit itself, the Gramme, is, therefore, .00058 Gm. or nearly .06 per cent. lighter than was intended. But as the units of volume were made correspondingly smaller, one milliliter (actual) being the volume of one Gramme (actual) of water, and one Liter (actual), the volume of one Kilogramme (actual), this error in the construction of the original Kilogramme weight has no practical bearing.

Table A.

10 milligrammes (mg.) = 1 centigramme (cgm. or cg.)
10 Centigrammes = 1 decigramme (dgm. or dg,)
10 decigrammes = 1 Gramme (Gm.)
10 Grammes = 1 Dekagramme (Dgm. or Dg.)
10 Dekagrammes = 1 Kilogramme (Kgm. or Kg.)
10 Kilogrammes = 1 Myriagramme (Mgm.)

As already stated, the final *m* in these abbreviations is frequently omitted.

Table B.

Myria gramme		*Kilo grammes*		*Hecto grammes*		*Deka grammes*		*Grammes*		*deci grammes*	*centi grammes*	*milli grammes*
1	=	10	=	100	=	1000	=	10000	=	100000	= 1000000	= 10000000
		1	=	10	=	100	=	1000	=	10000	=	100000 =	1000000
				1	=	10	=	100	=	1000	=	10000 =	100000
						1	=	10	=	100	=	1000 =	10000
								1	=	10	=	100 =	1000
										1		10 =	100
												1 =	10

Units in Common Use.—In prescriptions, and in the U. S. Pharmacopœia, only one unit of weight—the Gramme— is used. In many scientific books and periodicals the deci gramme, centigramme, and milligramme are used in addi tion. The Kilogramme is used in commercial transactions, and is frequently abbreviated to *Kilo*.

METRIC PRESCRIPTIONS.

Rules.—1. All volumes should be expressed in cubic centimeters, and all weights in Grammes.

2. Arabic numerals should be used in all cases; and the numbers should be placed before the abbreviations. Thus, 25 Gm., 160 Cc., 5 cm., etc.

3. Since so much depends upon the proper placing and the proper reading of the decimal point, special precautions should be observed to avoid a chance for a mistake. It is a common practice to draw a vertical line in the proper place on the prescription blank, and to write whole numbers of

cubic centimeters or of Grammes to the left of the line, and the fractions beyond the line. Thus the decimal point is done away with.

Example.—

℞	Quin. sulph.	2	
	Ferri phos.	8	75
	Potass. citr.	8	75
	Syr. calc. lactophos.	125	
	Aquae	15	
	Elix. Arom. q. s. ad	500	

Since it is customary in this country to prescribe all liquids by measure, and all solids by weight, there is no difficulty in determining which numbers in a prescription stand for cubic centimeters, and which for Grammes. quinine sulphate being a solid, the "2" following this item in the prescription given, stands for 2 Gm. But the "125," expressing the quantity of the syr. calcium lactophosphate, obviously means 125 Cc.; for the article is a liquid, and hence is to be measured.

If the vertical line is not made use of, every decimal fraction in the prescription should be written with a cipher before the decimal point. Thus, 0.75 Gm. in place of .75 Gm.; 0.1 Cc. in place of .1 Cc. This precaution makes it less probable that imperfections in the paper, or accidental markings be mistaken for decimal points. The German practice of using a comma (,), in place of a point, is also to be recommended. However, the vertical line removes the chances for such mistakes entirely.

*Reading Metric Quantities in Prescriptions.—*A whole number expressing a metric quantity is always read as a simple denominate number, and not as a compound number; that is, only one unit is used, no matter how large the number. Thus, 3450 Gm. is read—three thousand four hundred and fifty Grammes;—not three Kilogrammes, four Hectogrammes, and five Dekagrammes, which would be unnecessarily cumbersome. 6565 Cc. is read—Six thousand five

hundred and sixty-five cubic centimeters—not six Liters, etc., etc.

Fractions of cubic centimeters are read as tenths or hundredths, as the case may be. Fractions of Grammes are read as so many of the lowest unit in the fraction, it being remembered that the first decimal place belongs to deci-grammes, the second to centigrammes and the third to milligrammes. According to this rule 0.5 Gm. would be five decigrammes; 0.55 Gm., fifty-five centigrammes; 0.555 Gm., five hundred and fifty-five milligrammes. In case of a fourth decimal, this is read as so many tenths of milli-grammes; and .3575 Gm., as three hundred and fifty-seven and five-tenths milligrammes.

Some pharmacists ignore the units, decigramme and centigramme, and read all fractions of grammes as milli-grammes. Thus 0.5 Gm. would be five hundred milli-grammes, and 0.55 Gm., five hundred and fifty milli-grammes.

In dictating prescriptions by telephone, especially if there are mixed decimals to dictate, the plan of reading the numerals from left to right (in place of the whole numbers) should be adopted. The pharmacist can then copy the numerals as fast as read, and need not hold the entire num-ber in his mind—a task which is very trying, and may lead to error.

To illustrate: the prescription—

R	Arsenous acid	.065
	Ext. opium	.48
	Quinine sulphate	8.75
	Make 65 pills.	

Would be telephoned—

Arsenous acid—point—nought—six—five,
Ext. opium—point—four—eight,
Quinine sulphate—eight—point—seven—five.
Make 65 pills.

Of course *Grammes* would be understood.

Metric Prototypes.

As has been stated, the metric system was based on the $\frac{1}{10000000}$ of the earth's quadrant. A bar of platinum was constructed of this length, and was deposited in the French Archives, to serve as a prototype or model for the meter measures intended for actual use.

There was also constructed, and deposited in the French Archives, a weight of platinum of such size as to counterpoise in vacuo one cubic decimeter of water at its greatest density. This weight constituted the fundamental standard of mass, and was to serve as a prototype or model for the Kilogramme weights (and indirectly for the other metric weights) intended for actual use.

The metric system was adopted by France in 1795. The prototypes referred to became the legal reference standards of France shortly after the adoption of the system.

In 1875 an International Metric Convention was held in Paris, the United States participating. This convention called into being an International Bureau of Weights and Measures, the first duty of which bureau consisted in preparing an international standard Meter bar, and an international standard Kilogramme weight, and duplicates of these for the seventeen countries which had contributed to the support of this bureau.

It was decided that the international prototypes and their duplicates should be made to equal (the Meter bars in length, and the Kilogramme weights in mass) the prototypes of the French Archives; and should be constructed of an alloy of 90 parts of platinum and 10 parts of iridium, a composition selected on account of its hardness and its resistance to the action of atmospheric gases.

Of the 30 Meter bars and 31 Kilogramme weights made, one Meter bar and one Kilogramme weight were selected as international prototypes and placed in the charge of the international bureau. The others were distributed among the countries which had called the bureau into existence. The distribution was effected by lot, the United States drawing Meters No. 21 and No. 27, and Kilogrammes No. 4 and No. 20.

Meter No. 27 and Kilogramme No. 20 were selected as our National Prototypes, and are carefully preserved in the United States Office of Weights and Measures, which is a branch of the Treasury Department. The Meter No. 21 and the Kilogramme No. 4 are used as working standards.

While the 30 Meters and the 31 Kilogrammes were made as nearly alike as it was possible to make them, it was found that they were not precisely alike. But the difference between the International Prototypes and the several national prototypes was in each case determined with the utmost care. Thus our Na-

tional Kilogramme (No. 20) was found to be .00003 Gm. too light; and this fact must be taken cognizance of in the standardizations of other weights.

The two National Prototypes—the Meter No. 27 and the Kilogramme No. 20—are at the present time the ultimate reference standards for all weights and measures in use in the United States, with the sole exception of the weights used in the U. S. mints, which weights are by law still referable to the standard troy pound received from England in 1827.

Advice to the Student.

The student is advised to acquaint himself with the metric length units by the use of a metric rule; with the volume units by means of measuring vessels graduated in cubic centimeters and Liters; with the units of mass, by means of a set of metric weights. The Gramme, and the cubic centimeter should be known to the pharmacist as the pound and pint are known to the grocer—from actual use of the weights and measures. It is a mistake to think of the Liter as equivalent to so many fluid ounces, and of the Gramme as so many grains. Such equivalents have their uses; but the student must become familiar with the metric units by using measures and weights;—not through equivalents. To learn French properly, one must learn to *think* in French—not to think in English and then to translate. In like manner, one must learn to *think* in metric units—to guess at the diameter of a filter in centimeters, the capacity of a flask in cubic centimeters, the weight of a mass of quinine in Grammes. As long as the metric units are abstract ideas, the metric system will appear intricate and hard to master; but when these units find expression in something material—in graduated measures and sets of weights— all difficulty disappears at once.

Problems and Exercises.

1. Read the following metric expressions: (a.) 6560 c.c.; (b.) .02 L.; (c.) 2 L. expressed in c.c.; (d.) 1.645 Gm.; (e.) 65 mg.; (f.) 6 cg.; (g.) 6 dg.; (h.) 6 Kg.; (i.)

6 Kilo.; (j.) 17 M.; (k.) 7 cm.; (l.) 700 mm.; (m.) 6789.123 M.; (n.) 6789.1 c.c.; (o.) 6789.123 Gm.

2. Write in numbers, followed by the proper abbreviations:—(a.) six milligrammes; (b.) sixteen centigrammes; (c.) six tenths milligrammes; (d.) six Liters; (e.) six and six tenths milliliters; (f.) six and six tenths cubic centimeters; (g.) six hundred milligrammes.

3. By moving the decimal point read—(a.) 6000 c.c. as L.; (b.) 1455 Gm. as Kg.; (c.) 414 mm. as M.; (d.) .45 Gm. as cg.; (e.) .45 Gm. as mg.; (f.) 40 mg. as Gm.; (g.) 4 dg. as mg.

4. Supply the proper abbreviations in the following formula:—

Guaiac	12	5
Potass. carbonate		6
Pimenta	3	
Pumice	6	
Alcohol	43	5
Water	43	5
Diluted alcohol q. s. ad	100	

Addition.

5. Add: 2Kg., 43 Gm., 42 cg., 425 mg.

Solution.— 2 Kg. =   2×1000 = 2000   Gm.
              43 Gm. =   43   "
              42 cg. = 42÷100 =   .42   "
              425 mg. = 425÷1000 =   .425   "
                                        ————————
                                        2043.845 Gm.

Suggestion.—To simplify addition and subtraction, express all lengths in Meters, all volumes in cubic centimeters, all weights in Grammes. Then weights may be added to weights, volumes to volumes, and lengths to lengths, in the same manner in which abstract numbers are added.

6. Add: 10 L., 100 c.c., 5.6 L., 3.4 c.c. Ans. 15703.4 c.c.

7. Add: 2 Kg., 4 Dg., 500 Gm., 32 mg., Ans. 2540.032 Gms.

8. Add: 2 cm., 25 cm., 5 M., 500 mm., 13 Km.

9. Add: 5 cg., 50.5 mg., 5.5 Gm.

10. Add: 6 Kg., 20 Hg., 200 Dg., 2145 Gm. Ans. 12145 Gm.

SUBTRACTION.

11. Subtract 345 c.c. from 5 L.

Solution.— 5 L. = 5000 c.c.; and 5000 c.c. — 345 c.c. = 4655 c.c.

12. Subtract 345 mg. from 140.002 Gm.

Solution.— 345 mg. = .345 Gm.; and 140.002 Gm.— .345 Gm. = 139.657 Gm.

Subtract:

13. 1 cm. from 500 mm. Ans. 490 mm.

14. 2 L. from 6050 c.c. Ans. 4050 c.c.

15. 3.5 c.c. from 1 L. Ans. 996.5 c.c.

16. 1.4 mg. from 10 Gm. Ans. 9.9986 Gm.

17. A druggist making solution of lead subacetate finds that his evaporating dish plus contents weighs 757 Gm. The dish itself weighs 289.02 Gm. How much water must be added to make the contents weigh 500 Gm? Ans. 32.02 Gms.

MULTIPLICATION.

Remarks.—The product is always in the same unit [denomination] as the multiplicand. If mg. are multiplied, the product will be mg.; if Gm. are multiplied, the product will be Gm.; etc.

If a length, volume, or weight is expressed in a compound denominate number—that is, if several units are used in expressing it—reduce to a simple denominate number before multiplying.

Remember that the decimal places in the product must equal the total number of decimal places for both factors.

That is, if the multiplicand has 3 decimals, and the multiplier 4, the product must have [3+4 =] 7.

18. Multiply 5.045 Gm. by .004.

Operation.—5.045 Gm.

$$\times \ .004$$

.02018 Gm.

19. Multiply 345 mg. by 856. Ans. 295320 mg. = 295.320 Gm.

20. Multiply 50.5 c.c. by 7.058. Ans. 356.429 c.c.

21. A prescription is received for 48 capsules, each to contain .195 Gm. of mercurial mass, .12 Gm. of comp. ext. colocynth, .15 Gm. of ext. gentian. How much must be weighed out of each ingredient?

Division.

Remarks.—The quotient is always in the same unit [denomination] as the dividend.

Remember that the quotient must have as many decimal places as those in the dividend exceed those in the divisor. If the decimal places in the divisor exceed those in the dividend, add cyphers to the latter until the decimal places equal those in the divisor.

When a denominate number expressing volume or weight is to be divided by another denominate number also expressing volume or weight, both must be in the same unit [denomination]. See prob. No. 27.

22. Divide 95.789 Gm. by 7.42.

23. Divide 74.2 mg. by .02.

24. Divide .04 Gm. by 64.

25. Divide 6 Kg. by 8. Ans. 750 Gm.

Suggestion.—Since the number in the dividend in problem No. 25 is smaller than the number in the divisor, reduce to Gm. before dividing.

Remember that the quotient must have as many decimal places as those in the dividend exceed those in the divisor.

26.   Divide 30 Kg. by 8.   Ans. 3750 Gm.

Suggestion.—Since the number in the dividend cannot be divided by 8 without a remainder, it is simpler to reduce 30 Kg. to Gm. before dividing.   It is not customary to express metric quantities by compound denominate numbers.

27.   A Seidlitz powder contains 7.75 Gm. of Rochelle salt.   How many powders could be made from 2 Kg. of the salt?   Ans. 258.

Miscellaneous Problems.

28.   A druggist receives four lumps of opium, weighing respectively (1.) 1 Kg. 20 Gm., (2.) 5 Hg. 3 Dg., (3.) 650.35 Gm., (4.) 205 Gm. 15 mg.   How many Gm. of opium does he receive?   Ans. 2405.365 Gm.

29.   Suppose opium were worth $13.50 per Kilo. What would the above consignment cost?   Ans. $32.47.

30.   A certain elixir is to contain .175 mg. of strychnine in each c.c.   How much strychnine must be weighed out for 3 L. of the elixir?   Ans. 525 mg.

31.   A certain prescription calls for 75 pills, each to contain 200 mg. of quinine sulphate.   How much of the latter must be weighed out?   Ans. 15 Gm.

32.   A prescription calls for 5.1 Gm. of pancreatin, to be mixed with 20.4 Gm. of sodium bicarbonate, and the mixture to be divided into powders weighing 1.7 Gm. each (amount for peptonizing 500 c.c. of cow's milk).   How many powders will the mixture make?   Ans. 15.

33.   ℞   Strych. sulph. | 06
                  Quin. sulph.   16 |
                  Ferri phos.   10 | 75
            Mix and divide into 85 pills.

How much strychnine sulphate, how much quinine sulphate, and how much ferric phosphate in each pill?

34. A pharmacist extracts 7 headache tablets with chloroform, for the purpose of dissolving the caffeine present. He evaporates the chloroformic solution to dryness in a beaker, and finds that the residue and the beaker together weigh 11.005 Gm. The beaker itself weighs 10.38 Gm. How much caffeine in each tablet? Ans. .08928 Gm., which read, eighty-nine and twenty-eight hundredths milligrammes.

B. English Systems Customary in the United States.

While the metric system has had legal sanction since 1866, has since been adopted for all scientific work, and is the official system of our pharmacopœia, it has not as yet displaced the cumbersome English Systems in our every-day business transactions. Lumber is still sold by the foot, cloth by the yard, coal oil by the gallon, and meat by the avoirdupois pound. For prescription work the use of the old English troy weight—now obsolete in that country—is still quite general in the United States.

1.   Linear Measure.

The English linear measure, with its units of inch, foot, yard, etc., was originally derived from the average length of the barley corn. According to an English law of the year 1324, "three barley corns, round and dry, shall make an inch, and twelve inches a foot." But at the present time the inch is defined in England as the $\frac{1}{39.13929}$ of the length of the second's pendulum, which latter is therefore the natural standard of the English linear measure, and through the same, of all the English systems of measure and weight.*

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*The length of a pendulum determines the time of its vibrations. The shorter the pendulum, the shorter are its vibrations; the longer the pendulum, the longer and slower are its vibrations. A pendulum 39.13929 inches in length will always make one complete vibration ("swing-swang") per second, provided the pendulum is placed in a vacuum, the temperature is 62 degrees F., the altitude is that of the sea level, and the latitude, that of London. Conversely, a pendulum, beating seconds of time under the aforementioned conditions is bound to be just 39.13929 inches in length. And since a second's pendulum can be constructed as often as necessary, it serves admirably as a natural standard,— i. e., as a check upon the material standards in use.

The lack of simplicity in the relationship between the inch and the length of the second's pendulum—the latter being 39.13929 times that of the former—is readily accounted for by the fact that the length of the inch had become fixed by custom and by law, before the second's pendulum was selected as the natural standard.

In the United States the inch is now defined as equivalent to 25.4001 millimeters.

The yard is defined as $\frac{3600}{3937}$ Meters* All our measures and weights are now defined in metric terms, thus making the metric prototypes the standards for all the weights and measures in use in the United States, excepting weights used in the U. S. Mint, which are still regulated by law by the standard troy pound, received from England in 1827.

To repeat:—the American and the British yard are identical in length; but the former has for its prototype the Meter bar No. 27 (see page 17) and for its natural standard, the earth's quadrant; while the British yard is referable to a certain bar, with a gold peg near each end, a bar deposited in the office of the Exchequer, London;—and the natural standard for the British yard is the second's pendulum.

Table A.

12 inches (in.) = 1 foot (ft.)
3 feet = 1 yard (yd.)
   [Higher units are never used in pharmacy.]

Table B.

Yard		Feet		Inches
1	=	3	=	36
		1	=	12

*While $\frac{3600}{3937}$ Meters is the equivalent fixed by the law of 1866, and is accurate enough for all common purposes, the equivalent as determined by Capt. Clark for the British government is $\frac{36000000}{39370432}$.

2. Apothecaries' Fluid Measure (U. S. Wine Measure.)

The primary unit of the U. S. Wine Measure is the gallon, which is defined by the National Office of Weights and Measures as the volume in vacuo, and at 4° C., of 3785.434 Gm. of pure water.

Prior to 1893 the gallon was officially defined as 231 cubic inches, which shows its relation to the English Linear measure.

The Wine Measure, as used in this country, with its units of gallon, quart, and pint*, was brought from England, in which country, however, it has long since (1826) been superseded by the Imperial Measure.

The Apothecaries' Fluid Measure is the Wine Measure minus the quart unit, and with the addition of three units smaller than the pint.

The table, giving symbols and abbreviations, is as follows:

Table A.

60 minims ($\mathfrak{m}$) = 1 fluid drachm (f$\mathfrak{Z}$)
8 fluid drachms = 1 fluid ounce (f$\mathfrak{Z}$)
16 fluid ounces = 1 pint (O.)
8 pints = 1 gallon (Cong.)

O. is the abbreviation for the Latin word Octarius; Cong., for the Latin word Congius.

Table B.

Gallon	Pints	Fluid Ounces	Fluid Drachms	Minims
1 =	8 =	128 =	1024 =	61440
	1 =	16 =	128 =	7680
		1 =	8 =	480
			1 =	60

*The gill, which is ¼ pint, is obsolete, but is occasionally met with in old family recipes.

Apothecaries' Measure in Prescription Writing.—Roman numerals are used in connection with this system. It is customary to place the symbol or abbreviation before the number—not after it, as in case of metric prescriptions.

Example:

℞	Tinct. ferri chloridi		f ℥ iv
	Acidi phosphorici diluti		f ℥ iij
	Spiritus limonis		f ℥ ij
	Syrupi q. s. ad		f ℥ vj

Notes.—The dot over the numeral I is used as a precaution against ambiguity which might be occasioned by carelessness in writing. For example, V might stand for II or for V; but if the dots are systematically used, their absence would prove the character to be a V, while their presence would prove it to be a II.

In written prescriptions the terminal i is usually replaced by j as a further precaution against misinterpretation.

Many physicians omit the f, writing ℥ for f℥, and ℥ for f℥. Since liquids are measured, and solids weighed, the ℥ and ℥ stand respectively for f℥ and for f℥ in case of liquids, and for the weight units in case of solids.

ROMAN NUMBERS.

Numerals.—The Roman numerals are: I = 1; V = 5; X = 10; L = 50; C = 100; D = 500; M = 1000. [ss., from semis, Latin for half, is used in prescriptions.]

Rules for combining the numerals.—

1. Repeating a numeral repeats its value. Thus, III = 3; XX = 20; CCC = 300; etc. But since V, L, and D if doubled would give the equivalent of X, C, and M respectively, these three first-mentioned are never doubled. In place of VV, X is used; in place of LL, C is used; etc.

2. Numerals placed after a numeral of higher value are added to the latter.

Thus, VI = 5 + 1, or 6; XI = 11; XV = 15; XVII = 17; CLXVI = 166.

3. A numeral placed before a numeral of higher value is subtracted from the latter.*

Thus, IV = 5 — 1, or 4; IX = 9; XL = 40; XC = 90; XLVI = 50 — 10 + 5 + 1, or 46; XCVIII = 98.

4. A numeral placed between two higher numerals is always read in connection with the one which follows, and according to Rule 3, is subtracted.

Thus, XIV = 14; XXXIX = 39; LIV = 54; XLIV = 44; MDCCCLXXXIV = 1884; MDCCCVC = 1895.

Problems and Exercises.

36. Write the following expressions of volume as they should be written in a prescription: — (a) 45 minims, (b) 6 fluid drachms, (c) 14 fluid ounces, (d) 3 pints, (e) 1 gallon, (f) 2½ fluid ounces, (g) 2 fluid drachms, (h) and 30 minims.

REDUCTION DESCENDING.

37. Reduce 2 Cong. 1 O. 2 f ℥ 1 f ℥ 20 ♏ to ♏.

Suggestion.—Reduce the 2 gallons to pints by multiplying by 8; to the product add the 1 pint given; reduce the total number of pints to f ℥ by multiplying by 16; add the 2 f ℥ given; reduce f ℥ to f ℥ by multiplying by 8; add the 1 f ℥ given; reduce f ℥ to ♏ by multiplying by 60; finally add the 20 ♏ given.

38. Reduce ₁³₇ Cong. to f ℥.

Solution.—₁³₇ × 8 × 16 = ³⁸⁴₁₇ f ℥ = 22 ¹⁰₁₇ f ℥. Since our measures are not graduated in fractions, it is customary to reduce fractions to lower units.—

$$\frac{10}{17} \text{ f } ℥ = \frac{10}{17} \times 8 = \frac{80}{17} \text{ f } ℥ = 4 \frac{12}{17} \text{ f } ℥.$$
$$\frac{12}{17} \text{ f } ℥ = \frac{12}{17} \times 60 = \frac{720}{17} \text{♏} = 42 \frac{6}{17} \text{♏}.$$
Then ₁³₇ Cong. = 22 f ℥ 4 f ℥ 42 ₁⁶₇ ♏.

39. Reduce 3 O. 5 f ℥ to ♏. Ans. 25440 ♏. Reduce 6 Cong. to f ℥. Ans. 768 f ℥.

40. Reduce 3 ⅗ f ℥ to ♏. Ans. 1728 ♏.

*But only *one* numeral can be so subtracted.

Reduction Ascending.

41. How many fluid ounces in 6000 minims.

Solution.—In one fluid ounce there are 480 minims; (See Table B) hence there are as many fluid ounces in 6000 minims as 480 is contained in 6000. Ans. 12½ f ℨ.

42. A physician wishes to write a prescription for 64 one-fluid-drachm-doses of syrup of hypophosphites. What volume should he prescribe?

43. How should the volume of 8000 ℥ be expressed in order that it might be measured with the customary measures? Ans. 1 pint 5 f℥ 20 ℥.

44. Convert 666 fluid ounces into higher units—pints and gallons.

Solution.—Since there are 16 fluid ounces in a pint, 666 ÷ 16 = number of pints = 41 pints and 10 fluid ounces over. There being 8 pints in a gallon, 41 ÷ 8 = number of gallons = 5 gallons, and 1 pint over. The answer, therefore, is 5 gallons 1 pint 10 fluid ounces

Remark.—Volumes in apothecaries' measures are expressed by compound denominate numbers rather than by simple denominate numbers with fractions—unless the fraction be ½, in which case it may be used.

Addition.

45. Add the following volumes:—6 gallons; 4 gallons 3 pints 7 fluid ounces 5 fluid drachms; 3 pints 8 fluid ounces 4 fluid drachms.

Suggestion.—Arrange the denominate numbers under each other so that each unit will form a separate column. Add the column of the smallest unit first. If the sum is larger than the equivalent of the next higher unit, reduce to that unit, but enter the remainder under the column added. Proceed in this way until all columns have been added.

Operation.—	gallons	pints	fl. ounces	fl. drachms
	6	—	—	—
	4	3	7	5
	. .	3	8	4
	10	7	—	1

46. Add 15 gallons 5 fl. ounces.
           1 gallon 7 pints 12 fl. ounces.
           5 fl. ounces 6 fl. drachms.
          10 fl. ounces 4 fl. drachms.

SUBTRACTION.

47. Subtract 1 pint 12 fl. ounces from 5 gallons.

Suggestion.—Arrange subtrahend under minuend so that each unit of the former comes under the same unit in the latter;—i. e., gallons under gallons, pints under pints, etc. Subtract from right to left, that is, the lowest unit first, then the next higher, and so on. If then, in any column except the last one to the left, the subtrahend is found to exceed the minuend, one of the next higher unit in the minuend must be reduced.

Operation.—gallons pints fl. ounces. Gallons pints fl. ounces

5			=	4	7	16
—	1	12	=	—	1	12
4	6	4		4	6	4

48. Subtract $1\frac{4}{15}$ f $\frac{7}{3}$ from $1\frac{3}{4}$ f $\frac{7}{3}$.

Operation: $15 \times 4 = 60$. Hence 60 is the least common multiple.

$$1\frac{3}{4} = \frac{7}{4} = \frac{105}{60}$$
$$1\frac{4}{15} = \quad - \quad \frac{56}{60}$$
$$\text{Ans.} \quad \frac{49}{60} \text{ f } \frac{7}{3}$$

Note.—But this answer would require reduction to lower units in most practical problems. Another process would be to first reduce the subtrahend and minuend to lower units; then to subtract in the usual way.

49. A druggist taps a 36 gallon barrel of alcohol, making an air hole which he forgets to close. By keeping an account of the alcohol drawn off, he finds that the barrel supplied 31 gallons 4 pints 7 fl. ounces. How much was lost by evaporation?

MULTIPLICATION.

50. Multiply 5 pints 6 fl. ounces 2 fl. drachms 40 minims by 7.

Suggestion.—Multiply smallest unit first, then the next higher, and so on. In each case reduce the product to the next higher unit when that is possible, and write only the remainder under the unit multiplied.

Operation. —	O	f℥	f℥	♏
	5	6	2	40
				× 7

Ans.　　4 Cong.　5 O.　12 f℥　2 f℥　40 ♏

40 ♏ × 7 = 280 ♏ = 4 f℥ and 40 ♏
2 f℥ × 7 = 14 f℥; 14 f℥ + 4 f℥ = 18 f℥ = 2 f℥ and 2 f℥
6 f℥ × 7 = 42 f℥; 42 f℥ + 2 f℥ = 44 f℥ = 2 O. and 12 f℥
5 O. × 7 = 35 O.; 35 O.+ 2 O.= 37 O. = 4 Cong. and 5 O.

51.　Multiply $\frac{2}{7}$ ♏ by 60.
　　Operation:　$\frac{2}{7} \times 60 = \frac{120}{7} = 17\frac{1}{7}$ [♏]

52.　Multiply $\frac{3}{7}$ f℥ by $\frac{5}{6}$.
　　Operation:　$\frac{3}{7} \times \frac{5}{6} = \frac{15}{42}$ f℥.

53.　Multiply 50 ♏ by $\frac{1}{5}$.
　　Operation:　$50 \times \frac{1}{5} = \frac{50}{1} \times \frac{1}{5} = \frac{50}{5} = 10$ [♏]

Note.—It will be seen that multiplication by a fraction is virtually a method of accomplishing division.

54.　Multiply 600 ♏ by 20. Reduce product to higher units. Ans. 1 pint 9 fl. ounces.

55.　How much creosote is required to make 4 gross of 5 minim capsules?

DIVISION.

56.　Divide 10 gallons 5 pints 4 fl. ounces by 6.

Suggestion.—Divide from left to right, beginning with the highest unit. In case there is an indivisible remainder, reduce this to the next lower unit, and add to the number of that unit before the same is divided.

Operation.—	Cong.	O.	f℥
6)	10	5	4
	1	6	3 and 2 f℥ 40 ♏

10 Con. ÷ 6 = 1 Cong. and 4 over; 4 Cong. = 32 O.; 32 O. + 5 O. = 37 O. 37 O. ÷ 6 = 6 O. and 1 over; 1 O. = 16 f℥; 16 f℥ + 4 f℥ = 20 f℥. 20 f℥ ÷ 6 = 3 f℥ and 2 f℥ over. 2 f℥ = 16 fℨ ; 16 ℨ ÷ 6 = 2 fℨ and 4 fℨ over. 4 fℨ = 240 𝔪 ; 240 𝔪 ÷ 6 = 40 𝔪.

57. Divide ¼ 𝔪 by 5.
   Operation: ¼ ÷ $\frac{5}{1}$ = ¼ × $\frac{1}{5}$ = $\frac{1}{20}$ [𝔪]

58. Divide ¼ 𝔪 by ⅕.
   Operation: ¼ ÷ ⅕ = ¼ × $\frac{5}{1}$ = $\frac{5}{4}$ = 1¼ [𝔪]

Note.—Just as multiplication by a fraction is a method of effecting division, so a division by a fraction is a method of multiplication.

59. Divide 5 gallons 2 pints 2 fl. ounces by 8.

60. (a.) 3 O. ÷ 24; (b.) 4 Cong. ÷ 15; (c.) 4 f℥ ÷ 7.

61. With 8 fl. ounces 2 fl. drachms of oil of sandalwood in stock, how many 4 minim capsules could be filled? Ans. 990.

62. (a.) How many 2 fl. drachm doses in an 8 fl. ounce mixture? (b.) How many 15 minim doses in 1 pint?

3. Imperial Measure.

This is the fluid measure of Great Britain. It has been in use since 1826, in which year it superseded the wine measure, which is now the customary fluid measure of the United States.

The Imperial Measure is superior to the measure it displaced— to our fluid measure—inasmuch as it bears a simple relationship to the system of weight official in that country, namely the avoirdupois weight (page 32.)

The Imperial gallon, which is the primary unit, is defined as the volume of 10 av. pounds of pure water, at 62°F., and at a barometric pressure of 30 inches.

The Imperial fluid ounce is the volume of 1 av. ounce of pure water, at 62°F., and at a barometric pressure of 30 inches.*

*See foot note page 12.

Table A.

60 minims ($\mathfrak{M}$) = 1 fluid drachm (fl. drm.)

8 fluid drachms = 1 fluid ounce (fl. oz.)

20 fluid ounces = 1 pint (O.)

8 pints = 1 gallon (C.)

As explained on page 42, the first three Imperial units are smaller, and the pint and gallon larger than the corresponding units of the apothecaries' measure.

Table B.

Gallon.		Pints		Fl. Ounces.		Fl. Drachms.		Minims.
1	=	8	=	160	=	1280	=	76800
		1	=	20	=	160	=	9600
				1	=	8	=	480
						1	=	60

Problems in Imperial Measure.

63. (a.) How many fl. oz. in 5 C.?   (b.) How many fl. drm. in 5 O.*?   (c.) How many $\mathfrak{M}$ in 2 fl. oz.?

64. Reduce 4 C. 3 O. 14 fl. oz. 2 fl. drm. to $\mathfrak{M}$. Ans. 342840 $\mathfrak{M}$.

65. Convert 5000 $\mathfrak{M}$ to higher units—fl. drm.. fl. oz., etc.

66. Add 6 C. 4 O. 12 fl. oz.; 7 O. 10 fl. oz.; 3 fl. oz. 40 $\mathfrak{M}$.

67. Subtract 5 fl. oz. 4 fl. drm. from 5 C. Ans. 4 C. 7 O. 14 fl. oz. 4 fl. drm.

68. Multiply 2 fl. oz. 4 fl. drm. 40 $\mathfrak{M}$ by 24. Ans. 3 O. 2 fl. oz.

69. Divide 3 O. by 48. Ans. 1 fl. oz. 2 fl. drm.

70. Divide 1 C. 2 O. 2 fl. oz. 3 fl. drm. by 16.

71. A Canadian druggist receives a 4 pint bottle of Eaton's syrup from a British drug firm. How many 4 fl. oz. bottles can he fill?

4. Avoirdupois Weight.

All weighable merchandise, except jewelry and precious stones†, are generally bought and sold in this country by avoirdupois weight,—the metric weight not having been adopted as yet for every-day commercial transactions.††

*O in this paragraph stands or Imperial pint.

Unless the contrary is expressly indicated, gallons, pints, fl. ounces. fl. drachms, and minims are in this country understood to be those of the U. S. fluid measure.

†Sold by troy weight:—24 grains = 1 pennyweight; 20 pennyweights = 1 ounce; 12 ounces = pound.

††To assist in popularizing the metric system, the firm of E. R. Squibb & Sons has for several years put up their products in packages of metric quantities.

It should be distinctly understood that in the United States all drugs and chemicals which are not bought and sold by metric weight, are bought and sold by avoirdupois weight. *The apothecaries' weight is never used in commercial transactions*, not even in case of the most costly plant principles. An ounce bottle of morphine, or of quinine, contains 437½ grains; an eighth ounce bottle of aconitine contains ⅛ of 437½ grains.

The avoirdupois system of weight was introduced into England about 600 years ago. It is now known in that country as the Imperial weight, and is used in prescription compounding as well as for buying and selling. It is the official weight of the British Pharmacopœia.

In the United States, the units of the avoirdupois weight are officially defined in terms of metric units. The smallest unit, the grain, is defined as equivalent to 64.7989 milligrammes.

Table A.

437½ grains (gr.) = 1 ounce (oz.)
16   ounces   = 1 pound (lb.)

Table B.

Pound.		Ounces.		Grains.
1	=	16	=	7000
		1	=	437½

Note.—The avoirdupois weight includes a unit called av. drachm, which is $\frac{1}{16}$ of an ounce, and is equivalent to $27\frac{11}{32}$ grains. But this unit is seldom used, it being customary to divide the ounce into halves, quarters, eighths, etc.

Problems in Avoirdupois Weight.

72.   (a.) Reduce 16 av. lb. to oz.; (b.) 4 lb. to gr.

73.   (a.) How many grains in ⅛ oz. of cocaine? (b.) How many grains in ½ oz. bottle of atropine?

74. How many 3 gr. capsules could be filled from a 1 oz. bottle of quinine?

75. How many grains of cocaine hydrochloride would be left in a ⅛ oz. bottle after removing 30 gr.? Ans. 24$\frac{11}{16}$ gr.

76. How many ⅛ gr. morphine sulphate tablet triturates could be made from the contents of a ⅛ oz. bottle?

77. (a.) Reduce 50000 gr. to lb. and oz.; (b) 35000 gr. to lb.; (c.) 3000 gr. to oz.

78. A druggist desires to put up 5 gross of 10 gr. doses of Compound Acetanilid Powder (N. F.) How much of the latter must be made for the purpose? Ans. 1 lb. 200 gr.

79. 15 lb. 6 oz. + 6 lb. 10 oz. 100 gr. + 11 oz. 400 gr. = ?

80. From a 5 lb. can of opium the following quantities have been removed:—3 oz., 1¾ oz., 1.64 oz., 175 gr. How much remains?

81. The British Pharmacopœia gives the following formula for Gregory's powder: rhubarb, 2 oz.; light magnesia, 6 oz.; ginger 1 oz. How many 20 gr. doses would this make? Ans. 196 + doses.

5. Apothecaries' Weight.

This is a modification of the old English troy weight (See note page 31 and note page 34) the two being the same except in the units between the ounce and the grain.

The apothecaries' weight has never received legal recognition in this country; but since the apothecaries' grain is identical with the avoirdupois grain, and the latter is now defined in metric units based on the National Prototype Kilogramme, this reference standard may serve also for the apothecaries' system.

The smallest unit—the grain—was originally derived from the average weight of a grain of wheat*. Later the weight of a certain volume of water [1 cu. in. of water, in vacuo, and at 62° F. = 252.75965 gr] was used as the basis

of weight units in England; but the name *grain* for the smallest unit of weight has been retained to this day.

When the Pharmacopœia of London was compiled (in 1618), the troy (apothecaries') weight was decided upon as the weight to be used in compounding medicines. In England it has since been superseded by the Imperial weight (avoirdupois); but in this country the apothecaries' weight is so firmly established, that the inconveniences incident to the use of one system of weight for compounding, and a different system for buying and selling, will, no doubt, continue to trouble the pharmacist for many years to come.

Table A.

20 grains (gr.)	= 1 scruple (℈)
3 scruples	= 1 drachm (ʒ)
8 drachms	= 1 ounce (℥)
12 ounces	= 1 pound (℔)

Table B.

℔	ʒ	℥	℈	gr.
1 =	12 =	96 =	288 =	5760
	1 =	8 =	24 =	480
		1 =	3 =	60
			1 =	20

Notes.—(1.)   The apoth. pound is seldom used in pharmacy.

(2.)   The troy grain, apoth. grain, and the avoirdupois grain are identical.

(3.)   The apoth. ounce, and the troy ounce are the same, but the av. ounce is 42½ gr. smaller.

(4.)   The apoth. pound and the troy pound are the same, but the av. pound is 1240 gr. larger.

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*In 1266, in the reign of Henry III, the following law was enacted:—"An English silver penny, called a sterling, round and without clipping, shall weigh 32 grains of wheat, well dried and gathered out of the middle of the ear; and twenty pence (pennyweights) do make an ounce, and twelve ounces a pound." Subsequently, in the reign of Henry VII, about 1497, the pennyweight was divided into 24 parts, called grains, in place of into 32; thus creating the system of troy weight as used to this day.

Apothecaries' Weight in Prescriptions.—Roman numerals are used; and the numbers always *follow* the symbols or abbreviations.

In case of fractions, with the exception of ½, expressed by ss [abbr. for semis = one-half], Arabic numerals are used.

Example :

℞	Acidi arsenosi	gr. ⅕
	Strychninae sulphatis	gr. ⅓
	Quininae sulphatis	℈ ij
	Ext. gentianae	℈ ss
	Ft. pil. no. xx.	

Problems in Apothecaries' Weight.

82. Reduce 4 ℥ 2 ʒ 1 ℈ to gr. Ans. 2060 gr.

83. Reduce 7000 gr. to higher units—℈, ʒ, ℥ and ℔. Ans. 1 ℔. 2 ℥ 4 ʒ 2 ℈.

84. (a.) Reduce 1000 gr. to ʒ; (b.) 7000 gr. to ℔; (c.) 2000 gr. to ℥; (d.) 437½ gr. to ℥.

85. A certain formula for a horse powder is as follows:

Black antimony	℥ viij
Sulphur	℥ vj
Saltpetre	℥ vj
Resin	℥ v
Capsicum	ʒ iij ℈ j

How much will the formula make?

86. Subtract 2 ʒ 1 ℈ 12 gr. from 8 ℥.

87. The following prescription is to be filled, making eight (8) times the quantity:

℞	Ext. ergotae	ʒ j
	Ferri sulphatis	℈ jss
	Ext. nucis vomicae	gr. viij
	Hydrarg. chlor. corr.	gr. ss
	Make 30 pills.	

How much of each ingredient must be weighed out?

88. Divide 1 ℥ 1 ℈ 10 gr. by 8; (b.) by 80; (c.) by 800; (d.) by .08.

89. Divide 1 ℥ 4 ℈ by ¾; (b.) by $\frac{2}{13}$; (c.) by 1.034 (d.) by .0055.

90.	℞	Zinci phosphidi	℈ij
		Ext. nucis vomicae	℥ j
		Ext. gentianae	℥ iv
		Make 80 pills.	

How much of each ingredient in each pill?

Camphorae	gr. lxv
Ammonii carbonatis	gr. xlviij
Pulv. opii	gr. ix

Mix and divide into 3 gr. doses.
How many will it make?

92.	℞	Rhei	℥ ij
		Aloes	℥ iss
		Myrrhae	℥ j
		Saponis	℥ j
		Olei menthae piperitae	gr. viij
		Glucosi	℥ j ℈ j

Mix and divide into 4 gr. pills.
How many should be made? Ans. 104½ pills.

93.	℞	Make 48 pills each to contain	
		Atropine	$\frac{1}{75}$
		Morphine	$\frac{1}{8}$

Excipient q. s. to make a 2 gr. pill.

NOTE.—Since $\frac{48}{75}$ gr. of atropine cannot be weighed, proceed as follows:—Weigh out 1 gr. of atropine and mix with 74 gr. of some inert powder, thus making 75 gr. of mixture, of which each gr. represents $\frac{1}{75}$ gr. of atropine. Now weigh out 48 grains of this mixture—the amount containing $\frac{48}{75}$ gr. of atropine.

This rule can also be applied in case of solutions. Sup-

pose $\frac{1}{100}$ gr. of strychnine sulphate is to be contained in each fluid drachm of a 4 fluid ounce preparation. In 4 fl. ounces there are 32 fluid drachms; hence $\frac{32}{100}$ gr. of strychnine sulphate is required—an amount which cannot be weighed. Proceed thus:—weigh out 1 gr. of strychnine sulphate, and dissolve in enough water to make 100 minims. Each minim of this solution contains $\frac{1}{100}$ gr. of strychnine sulphate; therefore 32 minims should be used in the prescription.

CHAPTER II.

Relationship of Systems.

1. METRIC AND ENGLISH LINEAR MEASURES.

Official Equivalents.	Approximate Equivalents.
1 M = 39.37 in*	1 M = $39\frac{1}{3}$ in.
1 in. = 25.4001 mm.	**1 in. = 25 mm.**
1 ft. = .304801 M.	1 ft. = .3 M.
1 yd. = .914402 M.	1 yd. = .9 M.

Note.—All equivalents printed in bold faced type should be committed to memory.

While but one connecting link is really necessary, much laborious figuring may be avoided by having several such links—just as in a city many steps may be saved by having more than one bridge across a river. On the other hand, a multiplicity of equivalents is apt to prove confusing to the student and has been carefully avoided in these pages. For a complete table of equivalents see the U. S. Pharmacopœia.

When to employ accurate equivalents, and when approximate equivalents, must be decided in each case that comes up in practical pharmacy; but as a general rule, approximate equivalents are sufficiently accurate.

Problems.

Use Official Equivalents.

1. Reduce 69.325 M. to in.

Solution.—If 1. M. = 39.37 in., then 69.325 M. will equal 69.325 × 39.37 in. = 2729.3 in.

2. Reduce 69.325 in. to M.

Solution.—If 1 M. = 39.37 in., then 69.325 in. will equal as many M. as 39.37 is contained in 69.325.

$$69.325 \div 39.37 = 1.684 \text{ [M.]} \quad \text{(Ans.)}$$

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*According to Capt. A. R. Clark, who made the determination for the British Government, the equivalent is — 1 M = 39.370432 in.; but the official equivalent given above is sufficiently accurate for all practical purposes.

3. (a.) Reduce 60½ yd. to M.; (b.) 54¾ ft. to M.

4. Reduce 4 yd. 2 ft. 7½ in. to M.

Suggestion.—Reduce first to in.; then to M.

5. How many inches in 1 dm? in 1 cm? in 1 mm.?

6. (a.) Reduce 154 mm. to in.; (b.) 25 cm. to in.

7. A certain tube has an inside diameter of $\frac{3}{16}$ in. Give this in mm. Ans. 4.76 mm.

8. The tube is 4 ft. 8 in. long. Give in M. Ans. 1.42 M.

Use Approximate Equivalents.

9. Aconite is described in the U. S. P. as being 10 to 20 mm. thick, and from 50 to 75 mm. long. Give its dimensions in inches. Ans. $\frac{2}{5}$ to $\frac{3}{4}$ in. thick and 2 to 3 in. long.

10. Viburnum opulus is from 1 to 1.5 mm. thick, and about 30 cm. long. Give its dimensions in inches.

11. Swedish filtering paper is kept in the laboratory in the following diameters: 5.5 cm., 7 cm., 9 cm., 12.5 cm., 15 cm., 18.5 cm., 24 cm., 38.5 cm. Give these sizes in inches.

12. A druggist receives a prescription for a capsicum plaster 8 cm. by 12 cm. Give size in inches.

Ans. $3\frac{1}{5}$ by $4\frac{4}{5}$ in.

13. A druggist orders a 5 in. funnel (diameter across top); but the jobber sends a 12 cm. funnel. Is the one sent larger or smaller than the one ordered? How much?

2. Metric and Apothecaries' Fluid Measures.

Official Equivalents		Approximate Equivalents.	
1 c.c. (or ml.)	= **16.23 ♏.**	1 c.c.	= 16 ♏.
1 L.	= 33.814 f℥	**1 L.**	= **33.8 f ℥**
1 f ℥	= **29.57 c.c.***	**1 f ℥**	= **30 f℥**
1 Cong.	= 3.78543 L.		

Memorize the equivalents printed in bold faced type.

*More accurately, 29.5737 c c.

4

For calculating doses, and for all pharmaceutical work not requiring very great accuracy, the approximate equivalents may be used.

Problems.

Use Official Equivalents.

14.   Reduce 3 pints to c.c.

Solution.—3 pints = 48 f℥; 48 × 29.57 = 1419.36. Hence 3 pints = 1419.36 c.c.

15.   Reduce 1 Cong. 2 O. 6 f℥ to c.c.

Suggestion.—Reduce to f ℥; then to c.c.

16.   Reduce 93.29 c.c. to ℳ. . Ans. 1514 ℳ.

17.   Reduce 9.₄⁷₉ c.c. to ℳ.   Ans. 152 ℳ.

18.   Reduce (a.) 300 ml. to f ℥; (b.) 3.78543 L. to pints.

19.   Reduce 4.5 ml. to ℳ.   Ans. 73.035 ℳ.

20.   Reduce (a.) 40¾ ℳ to c.c.; (b.) 10 f ℥ to c.c.

21.   How many f ℥ will a 500 c.c. flask hold?

22.   How many c.c. will a pint bottle hold?   Ans. 473.12 c.c.

Use Approximate Equivalents.

23.   Express the following doses in metric measure:
(a.) croton oil, 1 — 2 ℳ; (b.) tr. belladonna, 5 — 15 ℳ. (c.) infusion buchu, 1 — 2 f ℥: (d.) tr. cinchona, 1 f ℥.

24.   Express the following formula in apoth. measure:

		Ans.
Castor oil	75. c.c.	2 f ℥ 4 f ʒ
Mucilage of acacia	37.5 c.c.	1 f ℥ 2 f ʒ
Orange flower water	25 c.c.	6 f ʒ 40 ℳ
Cinnamon water	62.5 c.c.	2 f ℥ 40 ℳ

25. Express in metric measure the following formula for a cough medicine:

Tr. opium	f℥ vj
F. e. ipecae	f℥ j
F. e. sanguinaria	f℥ j
Syr. squill	f℥ iij
Syr. wild cherry	f℥ ix
Syr. tar q. s. ad	O j

26. Express the following doses in apothecaries' measure:—sol. potass. arsenite, 0.3 c.c.; sol. potass. citrate, 15 c.c.; fl. ext. ipecac, 0.9 — 1.9 c.c.; spt. glonoin, 0.06 — 0.12 c.c.; tr. gelsemium, 0.6 — 1.25 c.c.; comp. decoction of sarsaparilla, 120 — 180 c.c.; inf. cinchona, 30 c.c.; oil of eucalyptus, 0.6 — 0.9 c.c.; syr. of tar, 3.7 — 7.5 c.c.

27. A druggist receives four "metric prescriptions": the first for a 60 c.c. solution, the second for a 120 c.c. liniment, the third for a 360 c.c. emulsion, the fourth for a 15 c.c. eye wash. State in fluid ounces the size of the bottle to be selected in each case.

Note.—American-made prescription bottles are commonly gauged in fluid ounces.

3. Apothecaries' and Imperial Measures.

The Imperial measure differs from our apothecaries' measure in two respects:—the Imperial minim equals but 0.96014 ℳ (U. S.); and the Imperial pint is divided into 20 Imperial ounces, while the pint (U. S.) contains only 16 f℥ (U. S.)

The equivalents usually employed, are:
1 Imperial minim = .96 ℳ (U. S.)
1 Imperial fluid drachm = .96 f℥ (U. S.)
1 Imperial fluid ounce = .96 f℥ (U. S.)
1 Imperial pint = 1.2 O. (U. S.) [accurately, 1.20017501].
1 Imperial gallon = 1.2 Cong. (U. S.) [accurately, 1.20017501].

28. Convert 6 fl. oz. Imp., into f℥, U. S.
Solution.—1 fl. oz. = .96 f℥. And 6 × .96 = 5.76.
Therefore 6 fl. oz. = 5.76 f℥.

But since our customary measures are not graduated in decimal fractions of each unit, convenience in measuring requires that such decimal fractions be reduced, so as to express the amount in integers of a lower unit (denomination). Hence .76 f℥ should be reduced to f℥; and should there be a fractional f℥ in the product, this fractional fluid drachm should be reduced to minims, as follows:

.76 × 8 = 6.08. Hence .76 f℥, = 6 f ℥ and .08 f℥; and since .08 × 60 = 4.80, .08 f℥ = 4.8 ℥.

Then 5.76 f℥ = 5 f℥ 6 f℥ 4.8 ℥.

29. Convert 6 f℥ into Imp. measure. Ans. 6 fl. oz 2 fl. drm.

30. Convert 1 Imperial pint into pints, f℥, f℥ and ℥ of U. S. measure. Ans. 1 O. 3 f℥ 1 f℥ 36 ℥. (U. S.)

31. Convert 3 Imperial pints into Apothecaries' measure.

32. Convert 3 pints, U. S. into Imperial measure.

33. Convert 6 pints 6 fluid ounces 6 fluid drachms Imp., into U. S., apothecaries' measure.

Suggestion.—Reduce to fluid drachms before converting into U. S. measure. And should the final answer contain a fraction of a drachm, reduce this to minims.

34. Convert the Imperial measures in the following Canadian prescription into U. S. apoth. measure:

Liq. ext. bellad.	10 fl. oz.
Camphor	1 oz.
Dist. water	2 fl. oz
Alcohol q. s. ad	20 fl. oz.

Note.—If the ingredients were all liquids, it would be allowable to read f ℥ in place of fl. oz. A somewhat larger volume of liniment would be dispensed in that case, but the relative proportions of the ingredients would not be changed. In the presence of solids, however, it is different; for the relationship between the Imperial ounce and the Imperial fluid ounce on the one hand, and the apoth. ounce and the apoth. fluid ounce on the other, is not the same. See page 30 and page 62. However, the difference is so small that it is usually ignored.

4. Metric and Imperial Measures.

The following equivalents may be used:

1 Imp. fl. oz. = 28.39 c. c.

1 c. c. = 16.9 ℥ (Imp.)

But the equivalents are seldom required and need not be memorized. Should it be necessary to convert metric measure into Imperial, or vice versa, and the equivalents are not at hand, convert the measure given to apothecaries' and this to the measure required, as indicated under problems No. 35 and No. 36.

35.   Convert 8 fl. oz. (Imp.) into c.c.

Solution.— $8 \times .96 = 7.68$ ∴ 8 fl. oz. $= 7.68$ f℥.

$7.68 \times 29.57 = 227.$ ∴ 7.68 f℥ $= 227.$ c.c.

36.   Convert 500 c.c. into fl. oz.

Process.— $500 \div 29.57 =$ number of f℥.

Number of f℥ $\div .96 =$ number of fl. oz.

37.   Convert 40 ℳ (Imp.) into c.c.   Ans. 2. 3 c.c.

38.   Convert 1 L. into Imperial measure—pints, fluid ounces, etc.   Ans. 1 pint 15 fl. oz. 1 fl. drm. 45 ℳ.

39.   Convert 50 gallons (Imp.) into Liters.

Note.—The sign ∴ stands for then, hence, or therefore.

Approximate Measures Used in the Administration of Medicine.

The following domestic measures are in common use:

1 Tumblerful $= 8$ f ℥ $=$ nearly 240 c.c.

1 Teacupful $= 4$ f ℥ $=$ nearly 120 c.c.

1 Wineglassful $= 2$ f ℥ $=$ nearly 60 c.c.

1 Tablespoonful $= \frac{2}{3}$ f ℥ $=$ nearly 20 c.c.

1 Dessertspoonful $= \frac{1}{3}$ f ℥ $=$ nearly 10 c.c.

1 Teaspoonful $= \frac{1}{6}$ f ℥ $=$ nearly 5 c.c.

1 Drop (watery liquids) $= 1$ ℳ $=$ about 0.06 c.c.

1 Drop (alcoholic liquids) $= \frac{1}{2}$ ℳ $=$ about 0.03 c.c.

The capacity of spoons, as given in this table, is correct for the modern standard tableware, silver or silverplated. Spoons which were manufactured many years ago, are found to be considerably smaller, the *teaspoon having a capacity of* 1 f ℥, *the dessertspoon of* 2 f ℥, *and the table-spoon of* 4 f ℥.   Many physicians still base their dose calculations on these equivalents which are no longer correct, and accordingly count 32 teaspoonfuls to 4 f ℥, whereas the patient using a modern spoon, divides the mixture into only 24 doses*.   In case of very active medicines this discrepancy between the equivalents as usually given and the actual ca-

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*By careful "heaping" the teaspoon can be made to hold nearly 2 f ℥ of syrup.

pacity of spoons used by the patient, should not be over-
looked by the pharmacist. If it is intended that a 1 f ℥ dose
be administered, the directions should read "¾ teaspoon-
ful, etc."

Another source of error in dosage is the use of a dessert
spoon in place of a tablespoon.

It should be remembered also that the drop is not a
definite volume, and that it seldom measures exactly 1 ♏,
even in case of pure water. The size of the drop is depend-
ent not only on the nature of the liquid, but is influenced by
the temperature, and by the size and shape of the mouth
of the vessel from which the drop is emitted. In case of
medicine droppers, (which are much used in prescription
work), the drop varies directly with the *outside* diameter
of the lower extremity of the tube.

Problems.

40. Write a prescription for 32 teaspoonful doses, each to
contain 1½ ♏ of tincture of aconite, and enough compound
elixir of taraxacum to make the proper volume.

(a.) Use the equivalents in the table.   (b.) Use com-
mon (old) equivalents.

41. ℞	Antim. et potass. tart.	gr. iv
	Liq. amm. acet.	f℥ iv
	Spt. aeth. nit.	f℥ ij
	Tr. aconiti.	f℥ j
	Syr. q. s. ad	f℥ viij

Teaspoonful 3 times a day.

(a.) Calculate the single dose for the first four ingre-
dients.

(b.) Use old equivalent.

42. ℞	Tincturae veratri viridis	3|5
	Spiritus aetheris nitrosi	30|
	Liquoris potassii citratis	20|
	Syrupi zingiberis q. s. ad	240|

(a.) Calculate the amount of each of the first three ingredients in a tablespoonful dose. (b.) Use old equivalents.

43. Write a metric prescription for 8 wineglassful doses, each to contain 0.5 c.c. of tincture nux vomica, and enough compound infusion of gentian (Br.) to make the proper volume.

44. ℞   Ac. hydrocyan, dil.   f℥ ij
        Aq. amygd. amar. q. s. ad   f℥ iv
        Teaspoonful.

(a.) How much dilute hydrocyanic acid in each f℥ dose?

(b.) How much of the acid would be administered for a dose if a common teaspoon were used?

METRIC AND APOTHECARIES' WEIGHTS.

Official Equivalents.	Approximate Equivalents.
1 gr. = 64.8* mg.	1 gr. = 65 mg., or .065 Gm.
1 ℥ = 31.1035 Gm.	1 ℥ = 31 Gm.
1 Gm. = 15.4324 gr.	1 Gm. = 15.4 gr.

In reducing gr. to Gm., use the equivalent, 1 gr. = .065 Gm., rather than the equivalent, 1 Gm. = 15.4 gr. For multiplication involves less work than does the process of division.

In computing doses, the equivalent, 1 gr. = 65 mg., is sufficiently accurate, and is generally used.

Problems.

Use Official Equivalents.

Convert 6 ℥ 2 ℥ 1 ℈ 12 gr. into Gm. Ans. 196.47 Gm.

45. (a.) Convert $\frac{3}{16}$ gr. into mg.; (b.) 6.4 gr. into mg. Ans. (a.) 12.1 mg.; (b.) 414.7 mg.

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*The official table gives 64.79; but as the accurate equivalent is 64.7989, 64.8 is nearer correct than 64.79.

†Accurately, 15.43235639 gr.

46. (a.) Convert 6.4 mg. into gr.; (b.) 6.042 Gm. into gr.

47. Convert 200 Gm. into apoth. units. Ans. 6 ℥ 3 ʒ 1 ꝺ 6½ gr.

Use Approximate Equivalents.

48. Give the following doses in metric weight: Arsenous acid. $\frac{1}{30}$ — $\frac{1}{15}$ gr.; atropine, $\frac{1}{100}$ — $\frac{1}{60}$ gr.; ext. belladonna leaves, $\frac{1}{6}$ — $\frac{1}{2}$ gr.; ext. rhubarb, 1 — 10 gr.; ferric citrate 3 — 20 gr.; salol, 5 — 30 gr.; sodium salicylate, 5 — 60 gr.; cascara sagrada, 15 — 60 gr.; coca, $\frac{1}{4}$ — 2 ʒ; Rochelle salt, 1 — 8 ʒ.

					Ans.
49.	℞	Bismuthi subcarb.	ʒ iij	=	11.7 Gm.
		Morphinæ sulph.	gr. j	=	0.065 Gm.
		Pulv. aromat.	ʒ j	=	3.9 Gm.
		Make 12 powders.			

(a.) Convert to metric weight. (b.) How many mg. of morphine sulphate in each dose?

Express the following doses in apothecaries' weight: Aconitine, .0001 Gm.; hyoscyamine sulphate, .0008 Gm.; ipecac (as emetic), 1.4 Gm., jalap, .65 — 1.3 Gm.; ext. nux vomica, .008 — .016 Gm.; antimonial powders, .2 — .52 Gm.; quinine sulphate, .065 — 1.5 Gm.; effervescent magnesium sulphate, 7.77 — 31.1 Gm.

51. Express the quantities in the following prescription in apothecaries' weight:

		Ans.		
℞	Quininæ sulphatis	3	25	= 2 ꝺ 10 gr.
	Strychninæ sulphatis		065	= 1 gr.
	Ferri phosphatis	6	50	= 1 ʒ 2 ꝺ
	Make 50 pills.			

7. METRIC AND AVOIRDUPOIS WEIGHTS.

Official Equivalents.	Approximate Equivalents.
1 gr. = 64.8* mg.	1 gr. = 65 mg.
1 oz. = 28.35 Gm.	1 oz. = 28⅓ Gm.
1 lb. = 453.592 Gm.†	1 lb. = 454 Gm.
1 Gm. = 15.4324 gr.	1 Gm. = 15.4 gr.
1 Kg. = 2.2 lb.‡	1 Kg. = 2.2 lb.

Problems.

Use Official Equivalents.

52. Convert (a.) 5 oz. into Gm.; (b.) 3 lb. into Gm.; (c.) 5 lb. into Kg.; (d.) 5 lb. 5 oz. 200 gr. into Gm. Ans. (d.) 2422.66 Gm.

53. Convert (a.) 60 Gm. into gr.; (b.) 600 Gm. into oz.; (c.) 6 metric pounds into av. pounds; (d.) 5675.45 Gm. to avoir. weight. Ans. (d.) 12 lb. 8 oz. 85.6 gr.

Use Approximate Equivalents.

54. Express the quantities in the following formula for menthol plaster in metric weight:

Menthol	2 oz.
Yellow wax	2 oz.
Resin	1 oz.
Lead plaster	15 oz.

55. (a.) Convert 5 lb. into Gm.; (b.) 5 oz. into Gm.; (c.) 5 gr. into mg.; (d.) 50 Gm. into gr.

56. Convert the quantities in the formula for compound cathartic pills into avoirdupois weight:

Com. ext. colocynth	800 Gm.
Mild mercurous chloride	600 Gm.
Ext. jalap	300 Gm.
Gamboge	150 Gm.

*Accurate equivalent is 64.7989 mg.
†Accurately, 453.592653 Gm.
‡Accurately, 2.20462 lb.

57. A druggist buys the following list of goods from E. R. Squibb & Sons:

> 5 Kg. Powd. acacia.
> ½ Kg. Iodoform.
> 2 Kg. Ether.
> 100 Gm. Lithium citrate.
> 25 Gm. Amyl acetate.
> 500 mg. Aconitine.

(a.) Convert these weights into avoirdupois.

(b.) Box and packing being figured at 8 Kg., how much would the gross weight be in avoir. units? Ans. 34 lb. 2 oz.

AVOIRDUPOIS (OR IMPERIAL) AND APOTHECARIES' WEIGHTS.

Equivalent:

1 gr. apoth. = 1 gr. av. or Imp.

Note.—Since the grain apoth. is identical with the grain avoir., any weight in one of these systems can be converted into weight in the other, by reducing to grains, and then to the higher units of that other system.

> Thus, 6 ℨ = 2880 gr. = 6 oz. 255 gr.
> 6 oz. = 2625 gr. = 5ℨ 3 ʒ 2 Ɖ 5 gr.

To use the equivalent, 1 ℨ = 1.1 oz.* would be practically no shorter (since the fraction would have to be reduced to smaller units), and the answer would be only approximately correct.

Problems.

58. (a.) Convert 2 ℨ into avoir. weight.

59. (b.) Convert 14¼ ℨ into avoir. weight.

59. (a.) Convert 15 ℨ 3 ʒ 2 Ɖ 10 gr. into avoir. weight.

(b.) Convert 3ℨ 3ʒ 2Ɖ 15 gr. into Imp. weight.

60. ℞   Ext. Stramonii   ℨij
         Adipis Benz.   ℥ij

Express quantities it avoir. weight.

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* 1 ℨ = 1.1 oz. av or Imp. (accurately, 1.097143).

Note.—Ointments. dusting powders, etc., are usually prescribed in quantities of 1 ℥ or more. But the 2 ℥ weight is the largest in the common set of prescription weights, and in many stores larger apoth. weights are not at hand. The proper procedure then is to reduce the apoth. weight to avoir. weight, in order that the counter weights, which are avoir., may be utilized. For instance, 2 ℥ of petrolatum is to be weighed. 2 ℥ = 2 oz. and 85 gr. So the 2 oz. weight of the counter set is used, together with a 1 ℨ weight, a 1 ℈ weight, and a 5 gr. weight of the prescription set. To weigh out 1 oz. when 1 ℥ is prescribed, involves a change in proportion of active medicine to base or diluent—a change which the pharmacist is not justified in making. except with the consent of the physician.

61.	℞	Sodium sulphate	℥ iij
		Sodium chloride	℥ viij
		Linseed, powd.	℥ viij

Suppose av. oz. were weighed in place of the apoth. ounces. How much difference would it make in the weight of the mixture?

Note.—In this prescripion the ℥ is the only unit used. And should avoir. ounces be dispensed in place of apoth. ounces. the proportions would not thereby be changed. There would still be 3 parts of sodium sulphate to 8 parts of the other ingredients. So there could be no serious objection to such a change.

62. (a.) Convert 3 oz. av. into apoth. weight. Ans. 2 ℥ 5 ℨ 2 ℈ 12½ gr.

(b.) Convert 5 oz. Imp. into apoth. weight. Ans. ℥ 4 ℨ 1 ℈ 7½ gr.

(c.) Convert 3 oz. 300 gr. into apoth. weight.

(d.) Convert 7 ½ oz. into apoth. weight.

63. A pharmacist dispenses ℨ iv of aristol from a 1 oz. package. How many grains remain? How many ℨ?

64. How many 1 ℈ doses of bismuth sub-nitrate could be dispensed from a 4 oz. package of the salt?

CHAPTER III.

VOLUMES AND WEIGHTS.

A. Specific Gravity (Relative Density, Specific Weight.)

By weighing equal volumes of various substances the fact is made apparent that hardly two substances can be found which weigh exactly alike volume for volume. Glycerin weighs one and one-fourth as much, volume for volume, as water. Ether is not quite three-fourths as heavy as water. Mercury is nearly twenty-three times as heavy as lithium, but not quite twice as heavy as iron. Thus the relation between weight and volume—in other words, the density,—differs with nearly every substance, but is always (under like conditions) the same for the same substance. This being true, density serves as a characteristic, as an "ear-mark," by which substances may be identified, or their purity be determined.

The most convenient way of expressing the density of a substance is by comparison with the density of another substance. The standard selected for such comparisons, for solids and liquids, is pure water*, the density of which is taken as unity—as 1.000. The density of any substance twice as heavy as water may then be expressed by 2.000; the density of a substance one-half as heavy as water, by .5; —these numbers indicating not weights, but ratios between weights.

When density is thus expressed (by comparison), it is properly called *relative density;* but its synonym, *specific gravity*, is more generally used, and will be used in the succeeding pages.

To repeat : *Density* is the relation which the weight of a body bears to its volume. *Specific gravity* is the density of a body as compared with the density of water, or with some other arbitrarily established standard.

Since the volume, and hence the density, of a body varies with the temperature, it is necessary to have a stand-

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*For gases, hydrogen at 0°C is taken as the standard of density.

ard temperature for specific gravity determinations. The temperature adopted by the U. S. Pharmacopoeia is $15°$ C., both for the standard—water—and for the substance of which the specific gravity is to be determined. This is expressed by

$$\frac{15° \text{ C.}}{15° \text{ C.}}$$

In Europe it is customary to make the determination at [or near] $15°$ C., but to compare with water at $4°$ C., the temperature at which water reaches its greatest density. These temperatures are expressed by

$$\frac{15° \text{ C.}}{4° \text{ C.}}$$

Calculating Specific Gravity.

To find the specific gravity of a body divide its weight by the weight of an equal bulk of water. Fractions in the quotient are stated as decimals; and in case these are interminate, they are usually carried to the third place.

The method employed in the determination of the *equal bulk of water,* varies with the nature of the substance under examination. In case of liquids, a small bottle is completely filled with water at the proper temperature, and weighed. Then the same bottle is filled with the liquid, and weighed. In each case the weight of the bottle itself is subtracted, giving in the latter case the net weight of the liquid, and in the first case the net weight of an *equal bulk of water.**

Problem.—A bottle holds 96.54 Gm. of water, and 94.78 Gm. of a certain oil. What is the sp. gr. of the oil?

Operation: 94.78 ÷ 96.54 = .981
(wt. of body of oil) ÷ (wt. equal bulk of water) = sp. gr.

The specific gravity of a solid, in mass, is found as follows: The body is weighed in air, in the usual manner. Then it is weighed in water being suspended in the latter from a balance arm by means of a hair. In water the body

*Another method is to make use of floats or buoys which indicate the sp. gr. of the liquid by the depth to which they sink. Such instruments are called hydrometers. The graduated scale on a modern hydrometer indicates the sp. gr. directly; but the older instruments carry arbitrary scales, some of which, notably those of Beaume, are still in use. For relation of degrees Beaume to sp. gr. see chapter XI.

is found to weigh less than in air. The difference between the two weights (the loss) is due to the buoyant force of the water, and this is exactly equal to the weight of just as much water as the body displaces. In other words, *the loss is exactly equal to the weight of an equal bulk of water*.

Problem.—A piece of ore weighs 5.4 Gm. in air. Suspended in water, from the arm of a balance, it weighs 4.01 Gm. Calculate the sp. gr. of the ore.

Operation.—Wt. in air $=$ 5.4 Gm. Wt. in water $=$ 4.01 Gm.

Loss in water $=$ 1.39 Gm. (wt. of equal bulk of water). Then 5.4 Gm. $\div$ 1.39 [Gm.] $=$ 3.884 (sp. gr.)

If the solid is found to be lighter than water, a sinker must be used to make complete immersion possible, thus making the calculation more complicated.* If the solid is soluble in water, another liquid in which the solid is insoluble must be selected, and this taken cognizance of in the calculation.†

Problems.

1. A certain bottle holds 500 Gm. of water. Of a certain solution it holds 650 Gm. Calculate the sp. gr. of the solution. Ans. 1.3.

---

*Problem.—A piece of paraffin weighs 2.895 Gm. Attached to sinker the total weight is 14.086 Gm. The sinker and paraffin in water weigh 8.258 Gm., while the sinker by itself in water weighs 8.652 Gm. Calculate sp. gr. of the paraffin.

Operation.—Wt. of sinker in air....................................11.191 Gm.
Wt. of sinker in water................................... 8.652 Gm.

Wt. of water displaced by sinker...................... 2.539 Gm.
Wt. of paraffin plus sinker in air.............?........14.086 Gm.
Wt. of paraffin plus sinker in water.................... 8.258 Gm.

Wt. of water displaced by paraffin plus sinker........ 5.828 Gm.
Wt. of water displaced by sinker...................... 2.539 Gm.

Wt. of water displaced by paraffin...................... 3.289 Gm.
Then 2.895 (wt. of paraffin in air) $\div$ 3.289 (wt. of equal bulk of water) $=$ .880 (sp. gr. of paraffin.)

†Problem.—A crystal of alum weighs 3.824 Gm. in air, and 1.901 Gm., suspended in oil of turpentine, having a sp. gr. of .860. What is the sp. gr. of the alum?

Operation.—Wt. of alum in air   3.824 Gm.
            Wt. of alum in oil turp.   1.901 Gm.
            Wt. of oil turp. displaced.   1.923 Gm.

Then 3.824 Gm. $\div$ 1.923 [Gm.] $=$ 1.988 (sp. gr. of alum, if oil turpentine were standard of density.)
Finally, 1.988 $\times$ .860 (sp. gr. of oil turp.) $=$ 1.709 (sp. gr. of alum, referred to water, the standard of density.)

2. A certain piece of metal weighs 10.10 Gm. in air, and 8.65 Gm. suspended in water. What is the sp. gr. of the metal? Ans. 6.965.

3. A certain iron cylinder holds 50 lb. of mercury. Of water it holds 3.69 lb. What is the sp. gr. of mercury?

4. What is the sp. gr. of a crystal which weighs 2.34 Gm. in air, and 1.18 Gm. suspended in water?

5. A certain bottle holds 245 gr. of water. Of oil of peppermint it holds 220.5 gr. What is the sp. gr. of the oil?

6. A certain bottle holds 3 oz. (av.) of water. Of nitric acid the same bottle holds 120.2607 Gm. What is the sp. gr. of the nitric acid. Ans. 1.414.

Note.—When a denominate number is to be divided by another denominate number, both must be in the same unit (denomination.)

7. An av. oz. of a volatile oil measures 35 c.c. What is the sp. gr. of the oil?

8. The weight of 5 c.c. of a certain liquid is 100 gr. What is the sp. gr? Ans. 1.296.

9. If a minim of water weighs .95 gr., and an av. oz. of an oil measures 500 ℥, what is the sp. gr. of the oil?

Solution.—500 ℥ of water weigh 500 × .95 = 475 gr.
500 ℥ of oil weigh 1 oz. = 437.5 gr.
Then 437.5 gr. ÷ 475 gr. = .921 (sp. gr.)

10. What is the sp. gr. of a liquid 1 lb. of which measures ½ L.?

Table of Specific Gravities.

The approximate specific gravity of the more common liquids should be memorized.

Water	1.00
Alcohol	0.82
Glycerin	1.25
Chloroform	1.5
Ether	0.7
Ammonia water	0.96
Sulphuric acid	1.83
Hydrochloric acid	1.16
Nitric acid	1.4
Syrup	1.3
Mercury	13.5
Etc.	

Specific Volume.

Specific volume expresses the same fact expressed by specific gravity ; namely, the density of a body as compared with the density of water.

To find the specific gravity, the weight of a body is compared with the weight of an equal volume of water. To find the specific volume, the volume of a body is compared with the volume of an equal weight of water. Specific volume is, therefore, the reciprocal of specific gravity. The greater the specific gravity of a body, the smaller is its specific volume ; and vice versa.

Calculating Specific Volume.—Divide the volume of the body by the volume of an equal weight of water.

$$\text{Sp.V.} = \frac{\text{vol. of body}}{\text{vol. of equal wt. of water.}}$$

Fractions in the quotient are expressed in decimals, and are carried to the third place, as a rule.

11. A certain weight of oil measures 60 c.c. The same weight of water measures 52 c.c. What is the specific volume of the oil?

　　　60 c.c.　　÷　　　　52 c.c.　　　　= 1.153

Vol. of oil. ÷ Vol. of equal wt. of water = Sp. V.

12. A certain weight of a certain acid measures 80 c.c. The same weight of water measures 4 f ʒ. What is the sp. v. of the acid?

Calculating Specific Volume from Specific Gravity.
Rule.—Divide the sp. gr. into 1.000. The quotient is the sp. v.

$$\text{Sp. V.} = \frac{1.000}{\text{Sp. Gr.}}$$

13. Glycerin has a sp. gr. of 1.25. What is its sp. v. ?
　　1.00 ÷ 1.25 (sp. gr.) = .800 (sp. v.)

14. Sulphuric acid has a sp. gr. of 1.835. What is its sp. v. ?

15. Ether has a sp. gr. of .725. What is its sp. v.?
Ans. 1.379.

Calculating the Specific Gravity from the Specific Volume.
Rule.—Divide the sp. v. into 1.000. The quotient is the sp. gr.

$$\text{Sp. Gr.} = \frac{1.000}{\text{Sp. v.}}$$

16. Chloroform has a sp. v. of .671. What is the sp. gr?
1.00 ÷ .671 (sp. v.) = 1.490 (sp. gr.)

B. Reducing Volume to Weight.

1. Cubic Centimeters to Grammes.

The weight of 1 c.c. of water is 1 Gm. The specific gravity of water is 1.000, it being the standard of density. One c.c. of any liquid having a specific gravity of 1.000, will, therefore, weigh 1 Gm. One c.c. of a liquid having a sp. gr. of 2.000, will weigh 2 Gm.; and one c.c. of a liquid having a sp. gr. of .75, will weigh .75 Gm. In short, *the specific gravity of a liquid indicates the weight in Grammes of one cubic centimeter of it.** Then any volume expressed in cubic centimeters may be converted into weight expressed in Grammes by multiplying the number of cubic centimeters by the specific gravity :—

No. of c.c. × sp. .gr. = No. of Gm.

Problems.

17. What is the weight in Gm. of 500 c.c. of glycerin, having a sp. gr. of 1.25?

500 × 1.25 = 625.
(No. of c.c.) × (sp. gr.) = (No. of Gm.)

---

*A c.c. of water weighs 1 Gm. at 4° C., and in vacuo, and the sp. gr. is taken at 15° C., and in air. In case great accuracy is required, correction must therefore be made for temperature, and for pressure. But such corrections are never necessary in pharmaceutical calculations.

18.   2 L. of sulphuric acid, sp. gr., 1.835, weigh how many Gm.? Ans. 3670 Gm.

19.   What is the weight in Gm. of 650 c.c. of alcohol, sp. gr., .82?

20.   Ether has a sp. gr. of .725. How many Gm. will 5.67 c.c. weigh? Ans. 4.1107 Gm.

21.   Calculate the weight in Gm. of 25 L. of syrup, sp. gr., 1.317.

2.   Fluid Ounces to Grains.

The weight of one fl. ounce of water, at 15° C., is 455.7 + gr. Water being the standard of density, it follows that any liquid having a sp. gr. of 1.000, will weigh 455.7 gr. per fl. ounce; that a liquid with a sp. gr. of 2.000, will weigh twice 455.7 gr. per fl. ounce; and that a liquid with a sp. gr. of .900, will weigh .9 of 455.7 gr. per fl. ounce. In every case 455.7 multiplied by the sp. gr. of the liquid will give the weight in grains of one fl. ounce. Then any volume in fl. ounces may be reduced to grains by the following rule:

$$455.7 \text{ gr.} \times \text{sp. gr.} \times \text{no. of f } \text{℥} = \text{wt. in gr.}$$

22.   Calculate the weight in gr. of 2 pints 3 fl. ounces of nitric acid, sp. gr., 1.414.

Solution.—455.7 gr. $\times$ 1.414 = 644.3598 gr. (wt. in gr. of 1 fl. ounce.)

2 pints 3 fl. ounces = 35 fl. ounces.

Then, 644.36 gr. $\times$ 35 = 22552.6 gr. (wt. of 2 pints 3 fl. ounces.)

Usually the weight in gr. is subsequently to be reduced to weight in higher units.

Note—When decimals in a product are dropped, this should be done with the least error:—1.158 for instance, should be given as 1.16, not as 1.15.

23.   (a.) Find weight in gr. of 14 f ℥ of mercury, sp. gr., 13.55. (b.) Express in higher units, avoirdupois.

24.   (a.) Calculate weight in av. lb. of 36 gallons of alcohol, sp. gr., .82. (b.) Calculate weight in av. lb. of 1 pint of syrup, sp. gr., 1.317.

25.   Calculate weight. in av. lb. of 1 pint of water.

26. Calculate weight in av. lb. of 1 pint of benzine, sp. gr., .67. Ans. .6978 lb.

27. Calculate weight in av. lb. of 1 pint of sulphuric acid, sp. gr., 1.835. Ans. 1.91 lb.

[Is it a fact that "a pint is a pound"?]

28. Calculate weight, in units of the apoth. system, of 1 O. 3 f ℥ 2 f ʒ 40 ♏ of alcohol, sp. gr., .82.

29. Calculate weight in Gm. of 1 gallon of ammonia water, sp. gr., .96. Ans. 3636.13 Gm.

30. Calculate weight in av. lb. of 8 L. of stronger ammonia water, sp. gr., .901.

3. Minims to Grains.

Since 1 fl. ounce equals 480 minims, and since 1 fl. ounce of water weighs 455.7 grains, each minim of water weighs $\frac{455.7}{480}$ grains.

But $\frac{455.7}{480}$ is too cumbersome a fraction for speedy work; a decimal fraction would be more convenient.

$$\frac{455.7}{480} = .9493$$

And this fraction may, for most practical purposes, be rounded off to .95.

Then, if .95 gr. is taken as the weight of 1 ♏ of water, the weight of 1 ♏ of any liquid must be .95 gr. × sp. gr.; and the rule for reducing ♏ to gr. must be—

.95 gr. × sp. gr. × no. of ♏ = weight in gr.

Problems.

31. Find weight in grains of 160 ♏ of solution of ferric chloride, sp. gr., 1.387.

Solution.—

.95 gr. × 1.387 = 1.31765 gr.

Wt. of 1 ♏ of water × sp. gr. = wt. of 1 ♏ of solution.

Then, 1.31765 gr. × 160 = 210.824 gr. (Ans.)

32. Find weight in gr. of 75 ♏ of sulphuric acid, sp. gr., 1.835. Ans. 130.74 gr.

33. Find weight in gr. of 200 ♏ of alcohol, sp. gr., .82.

34. Find weight in gr. of 120 ♏ of chloroform, sp. gr., 1.49. Ans. 169.86 gr.

4. OTHER UNITS APOTH. MEASURE TO APOTH. WEIGHT.

One of the chief advantages of the apothecaries' systems lies in this, that the three units of volume most commonly used in prescription work and the three most commonly used weight units are parallels. Thus, the smallest unit of volume, the minim, has its parallel in the grain, which, as has been seen, is, however, not exactly equivalent to a minim ; and just as 60 minims make 1 fl. drachm, so 60 grains make 1 drachm ; and as 8 fl. drachms make 1 fl. ounce, so 8 drachms make 1 ounce. It follows, then, that if 1 minim of water weighs .95 grains, 1 fl. drachm of water must weigh .95 drachms (ℨ), and 1 fl. ounce, .95 ounces (℥). Hence the following rule to reduce fl. drachms of a liquid to weight in drachms:

.95 ℨ* × sp. gr. × No. of f ℨ = weight in ℨ.

And the following rule to reduce fl. ounces to ounces :

.95 ℥* × sp. gr. ×No. of f ℥ = weight in. ℥.

Note.—If the student cannot harmonize this rule with the one given on page 57, he should carefully review pages 55, 56, and 57.

Problems.

35. What would be the weight in ℥ of 1 O. 6 f℥ of stronger ammonia water, having a sp. gr. of .91 ? Ans. 19 + ℥.

36. What would be the weight in ℨ of 3½ f ℨ of lactic acid, having a sp. gr. of 1.213 ? Ans. 4 ℨ.

*Exactly, .9493 gr., as explained on page 57.

37. What would be the weight in ℥ of 7¾ f ℥ of phosphoric acid, sp. gr., 1.71?

38. What would be the weight in ℥ of 2 O. of diluted alcohol, sp. gr., .938?

Reducing Weight to Volume.

1. Grammes to Cubic Centimeters.

As was explained on page 55, the specific gravity expresses the weight in Grammes of one cubic centimeter. Thus the expression, glycerin, sp. gr., 1.25, means that each cubic centimeter of glycerin weighs 1.25 Gm. Then 1.25 Gm. of glycerin will measure 1 cubic centimeter; 2.5 Gm. of glycerin will measure 2 cubic centimeters; and 50 Gm. of glycerin will measure as many cubic centimeters as 1.25 Gm., the weight of 1 cubic centimeter, is contained in 50 Gm.

Hence the rule—

Wt. in Gm. ÷ sp. gr. = vol. in c.c.

Problems.

39. Solution of ferric sulphate has a sp. gr. of 1.32. Calculate volume of 358.5 Gm. Ans. 271.59 c.c.

40. A formula calls for 246 Gm. of nitric acid, sp. gr., 1.414. But on account of the corrosive action of the acid on the balances, it is much more convenient to *measure* the acid than to weigh it. How many c.c. should be used?

41. A formula calls for 870 Gm. of sulphuric acid, sp. gr., 1.835. How many c.c. should be used. Ans. 474.1 c.c.

42. In making ferric chloride, 300 Gm. of hydrochloric acid is to be used. The acid having a sp. gr. of 1.163, how many c.c. should be measured out?

43. A certain solution having a sp. gr. of 1.4, is directed to be given in 2 Gm. doses. What would be the dose in c.c.?

[In Germany it is customary to compound all medicines, liquids as well as solids, by weight. It is also customary to state the dose in weight units.]

44. A certain tincture is directed to be given in 3 Gm. doses. It has a sp. gr. of .86. What should be the dose in ♏ ?

45. In a certain formula 1 ℥ of nitric acid, sp. gr., 1.414, is required. How many c.c. should be used? Ans. 21.9 c.c.

Suggestion.—Reduce 1 ℥ to Gm.; then to c.c.

46. A certain formula calls for 1 kg. of phosphoric acid, sp. gr., 1.71. How many c.c. should be used?

47. A formula calls for 5 oz. of nitric acid, sp. gr., 1.414. How many c.c. should be used.

2. GRAINS TO FLUID OUNCES.

As has been shown on page 56, the weight of 1 fl. ounce of any liquid may be calculated if the specific gravity is known, this being used as a multiplier for 455.7 gr., the weight of 1 fl. ounce of water.

Then, if the weight of 1 fl. ounce of the liquid is known, any given weight can be reduced to fl. ounces by dividing the given weight by the weight of 1 fl. ounce.

This may be expressed as follows:

Wt. of liquid in gr. ÷ (455.7 gr. × sp. gr.) = vol. in f ℥.

[And, since multiplying the divisor is the same as dividing the dividend, the no. of f ℥ may be found also by dividing the weight of the liquid in gr. first by 455.7 gr., then by the sp. gr. —

Wt. of liquid in gr. ÷ 455.7 gr. ÷ sp. gr. = vol. in f℥.

Problems.

48. Calculate the volume in f ℥ of 1 lb. of ether, sp. gr., .725.

Solution.—

$$1 \text{ lb.} = 7000 \text{ gr.}$$
$$455.7 \text{ gr.} \quad \times \quad .725 = 330.38 \text{ gr.}$$
wt. 1℥ of water × sp. gr. = wt. of 1 f℥ of ether.

(Then, 7000 gr. ÷ 330.38 (gr.) = 21.198. (Ans.)
(wt. given ÷ wt. of 1 ℥) = no. of f ℥.

49. Find volume in f ℥ of 1 lb. of water.

50.   Find volume in f ℥ of 1 lb. of chloroform, sp. gr., 1.49. Ans. 10.3 f ℥ ; or exactly, 10 f ℥ 2 f ℨ 28 ♏.

51.   Find volume in f ℥ of 1 lb. of mercury, sp. gr., 13.558.

52.   Find volume in f ℥ of 1 lb. of oil of lemon, sp. gr., .858. Ans. 17.9 f ℥, or 17 f ℥ 7 f ℨ 12 ♏.

53.   Find volume in f ℥ of 5℥ 3℥ 1 ℈ 10 gr. of solution of ferric chloride, sp. gr., 1.387.

54.   Find volume in pints of 5 lb. of nitric acid, sp. gr., 1.414.

55.   Find volume in c.c. of 4 lb. of hydrochloric acid, sp. gr., 1.163. Ans. 1954 c.c. 1563

56.   Find volume in L. of 50 lb. of glycerin, sp. gr., 1.25.

57.   Find volume in pints of 25 Kg. of glycerin, sp. gr., 1.25. Ans. 42.24 pints.

58.   One pound (av.) of ether, sp. gr., .725, would fil! how many 2 f ℥ bottles? Ans. 10.

59.   One hundred pounds of mercury, sp. gr., 13.558, would fill how many pint bottles? Ans. 7.

60.   How many fl. ounces in 2 Kg. of chloroform, sp. gr., 1.49? Ans. About 45.

61.   A carboy of stronger ammonia water, sp. gr., .901, contains 115 lb. of the water. How many pints does it contain? How many Liters?

62.   A carboy of sulphuric acid, sp. gr., 1.835, contains 142 Kg. How many cubic centimeters does it contain? How many fl. ounces? How many Liters? How many gallons?

63.   A druggist buys glycerin, sp. gr., 1.25, at 45c. per lb. and sells a pint at 80c. What is his profit on each pint?

64.   A druggist buys chloroform, sp. gr., 1.49 at 70c. per lb., and sells a Liter for $2.00. Does he gain or lose? How much? Ans. He loses 29c.

3.   GRAINS TO MINIMS.

Since 1 ♏ of water weighs .95 gr., .95 gr. multiplied by the sp. gr. gives the weight in gr. of 1 ♏ of any liquid and—
No. of gr. given ÷ (.95 gr. × sp. gr.) = vol. in ♏.*

---

*Or, No. of gr. given ÷ .95 gr. ÷ sp. gr. = vol. in ♏.

65. Find volume in minims of 200 gr. of chloroform, sp. gr., 1.49.

Solution.—   .95 gr.   ×   1.49   = 1.4155 gr.

(Wt. of 1 ♏ of water) × (sp. gr.) = (wt. of 1 ♏ of chloroform.)

Then—   200 gr. ÷ 1.4155 gr. = 141. (Ans.)

No. of gr. given ÷ wt. of 1 ♏ = No. of ♏.

66. Find volume in minims of 90 gr. of lactic acid, sp. gr., 1.213. Ans. 78 ♏.

4. Drachms and Ounces to Fluid Drachms and Fluid Ounces.

As was explained on page 58, 1 f ʒ of water weighs about .95 ʒ; and 1 f ℥ of water, about .95 ℥.

Then—, **No. of ʒ given ÷ (.95 ʒ × sp. gr.) = vol.** in f ʒ; and **No. of ℥ given ÷ (.95 ℥ × sp. gr.) = vol. in f ℥.**

The answers will be slightly high, but sufficiently accurate for practical purposes. The student should explain why these answers are slightly higher than answers obtained by rules on page 60.

67. Find volume in f ʒ of 6 ʒ of bromine sp. gr., 2.99.

68. Find volume in f ℥ of 8 ℥ of phosphoric acid, sp. gr., 1.71. Ans. 4.9 f ℥, or 4 f ℥ 7 f ʒ 21 ♏.

69. Find volume in c.c. of 8 ℥ of phosphoric acid, sp. gr., 1.71. Ans. 147.7 c.c.

70. Find volume in f ℥ of 250 Gm. of phosphoric acid, sp. gr., 1.71.

5. Imperial Ounces to Fluid Ounces.

An Imperial or avoir. oz. of water measures an Imperial fluid ounce. Hence— No. of Imp. oz. ÷ sp. gr. = Imp. fl. oz.

REDUCING AND ENLARGING FORMULAS.

Let us suppose that just 25 Gm. of compound morphine powder is wanted. The formula is as follows:

<div style="text-align:center">

Morphine sulphate......... 1 Gm.
Camphor ....19 Gm.
Glycyrrhiza ....20 Gm.
Precip. calcium carbonate...20 Gm.
                           ————
To make...............60 Gm.

</div>

Now 25 Gm. is $\frac{25}{60}$ of 60 Gm. So we must multiply the quantity for each ingredient by $\frac{25}{60}$, in order that the mixture may weigh 25 Gm. in place of 60 Gm. That is, we must divide by 60, which would give us the amount to be used for 1 Gm. of powder, and then multiply by 25, because we wish to make 25 times 1 Gm., namely, 25 Gm.*

From the above reasoning we may deduce the following general rule:

To reduce or enlarge a formula, multiply the quantity of each ingredient by a fraction of which the quantity [of the preparation] to be made is the numerator, and the quantity the formula makes is the denominator. In practice this fraction is always reduced to the simplest expression; $\frac{30}{60}$ becomes $\frac{1}{2}$; $\frac{25}{60}$ becomes $\frac{5}{12}$; $\frac{600}{1000}$ becomes $\frac{6}{10}$ or .6.

Problems.

1. How much vinegar of squill, and how much sugar are required to make 600 c.c. of syrup of squill?

Formula:

<div style="text-align:center">

Vinegar squill   450 c.c.
Sugar   800 Gm.
Water q. s. ad 1000 c.c.

</div>

---

*In practice cumbersome fractions are to be avoided when possible. The practical druggist would make 30 Gm. in place of 25; and since $\frac{30}{60} = \frac{1}{2}$, would avoid the lengthy calculation, and save enough time to compensate for the extra 5 Gm. of powder, should the latter be wasted.

The formula is for 1000 c.c., but we wish to make 600 c.c., which is $\frac{600}{1000}$ or .6 of 1000 c.c.

Hence each quantity must be multiplied by $\frac{600}{1000} = .6$.

Operation:

$$450 \text{ c.c.} \times .6 = 270 \text{ c.c.}$$
$$800 \text{ Gm.} \times .6 = 480 \text{ Gm.}$$
$$1000 \text{ c.c.} \times .6 = 600 \text{ c.c.}$$

2. How much iodine is required to make 1 pint of a tincture, a Liter of which contains 70 Gm. of the constituent?

Solution.— 1 O. = 16 f ℥; and 1 f ℥ = 29.57 c. c.

Accordingly 1 O. = (16 × 29.57) = 473 c.c.

Then 70 Gm. $\times \frac{473}{1000}$ [or .473] = 33.11 Gm., the amount of iodine for 1 pint.

3. Calculate the quantities for 1 gallon of soap liniment from the following formula:—soap, 70 Gm.; camphor, 45 Gm.; oil rosemary, 10 c.c.; alcohol, 750 c.c.; water, q. s. ad 1000 c.c.

4. Calculate the formula for 1 Kg. of tooth powder from the following formula:—Powdered soap, 4 oz.; precip. chalk, ½ lb.; camphor, 30 gr.; vanillin, 5 gr.; oil rose, 8 ℳ; powdered sugar, 2 oz.; magnesium carbonate, q. s. ad 1 lb.

Solution.— 1 Kg. = 2.2 lb. Hence each quantity is to be multiplied by $\frac{2.2}{1}$ that is, by 2.2.

$$4 \text{ oz.} \times 2.2 = 8.8 \text{ oz.}$$
$$\tfrac{1}{2} \text{ lb.} \times 2.2 = 1.1 \text{ lb.}$$
$$30 \text{ gr.} \times 2.2 = 66 \text{ gr.}$$
$$5 \text{ gr.} \times 2.2 = 11 \text{ gr.}$$
$$8 \text{ ℳ} \times 2.2 = 17.6 \text{ ℳ.}$$
$$2 \text{ oz.} \times 2.2 = 4.4 \text{ oz.}$$

Mag. carb. q. s. ad 2.2 lb. = q. s. ad 1 Kg.

Note.—Remember that the product is always in the same unit as the multiplicand.

5. The National Formulary gives the following formula for Dewee's Carminative:—magnesium carbonate, 50 Gm.; tr. asafoetida, 75 c.c.; tr. opium, 10 c.c.; sugar, 100 Gm.; water, q. s. ad. 1000 c.c.

(a.) Calculate quantities for 120 c.c.; (b.) for 4 f℥; (c.) for ½ Cong.; (d.) for 2 L.; (e.) for 3750 c.c.

The formula for compound syrup of squill is:—fl. ext. squill, 80 c.c.; fl. ext. senega, 80 c.c.; antimony and potassium tartrate, 2 Gm.; precip. calcium phosphate, 10 Gm.; sugar, 750 Gm.; water, q. s. ad 1000 c.c.

(a.) Calculate quantities for 1 O.; (b.) 180 c.c.; (c.) for 1 Cong.; (d.) for 5850 c.c.; (e.) for 2 O. 6 f ℥.

A formula for deep blue show globe color is:—cop‑ per sulphate, 15.5 Gm.; water, 250 c.c. Make solution, to which add—ammonia water, 75 c.c.; and then enough water to make 2 L.

(a.) Calculate formula for 5780 c.c. (b.) for 2 gallons. Ans. Copper sulphate, 58.67 Gm., water, 946 c.c., ammonia water, 283.9 c.c; and enough water to make 2 gallons.

Calculating Definite Weight from Parts by Weight.

"Parts-by-weight-formulas" are given in the U. S. Pharmacopoeia of 1880, in the latest edition of the German Pharmacopoeia (1900), and in many scientific publications. The advantage of such a formula lies in the fact that a part may mean a pound, an ounce (av.), an ounce (apoth.), a grain, a Gramme, a Kilogramme,—in short, any convenient unit of weight. But for formulas for liquids, "parts by weight" were never popular in the United States, because of the established custom in our country of *measuring* liquids.

Problems.

5. Calculate a formula for 5 lb. of salicylated talcum from the following formula of the German Pharmacopoeia of 1900:—salicylic acid, 3 parts; wheat starch, 10 parts; talcum, 87 parts.

Solution.—A part in this case is assumed to be a pound. Then the general rule, to multiply each quantity by the fraction of which the amount wanted is the numerator, and the amount the formula makes is the denominator, is applied. The amount wanted is 5 lb.; the formula makes 100. Hence each quantity is multiplied by $\frac{5}{100}$ or .05.

Thus we have—

Salicylic acid	3 lb. × .05 =	.15 lb.
Wheat starch	10 lb. × .05 =	.5 lb.
Talcum	87 lb. × .05 =	4.35 lb.

The fractions of pounds should, of course, be reduced to lower units.

6. Suppose 500 Gm. of the salicylated talcum are wanted. Each part is assumed to be a Gramme. Then—

$$3 \ \text{Gm.} \times \frac{500}{100} = \ 15 \ \text{Gm.}$$
$$10 \ \text{Gm.} \times 5 \ = \ 50 \ \text{Gm.}$$
$$87 \ \text{Gm.} \times 5 \ = 435 \ \text{Gm.}$$

7. Suppose 480 gr. are wanted for a prescription. Each part is assumed to be a grain. Then—

$$3 \ \text{gr.} \times \tfrac{480}{100} = \ 14.4 \ \text{gr.}$$
$$10 \ \text{gr.} \times \ 4.8 = \ 48. \ \text{gr.}$$
$$87 \ \text{gr.} \times \ 4.8 = 417.6 \ \text{gr.}$$

8. The German Pharmacopoeia of 1900 gives the following formula for powder of magnesia and rhubarb:— magnesium carbonate, 50 parts; eleosaccharate of fennel oil, 35 parts; rhubarb, 14 parts. (a.) Calculate quantities for 600 Gm. of the powder; (b.) for 2 Kg.; (c.) for 2 lb.; (d.) for 8 ℥; (e.) for 8 oz.; (f.) for 300 gr.; (g.) for 6 ℥ 2 ʒ 1 ℈ 10 gr.

Ans.	(a.)	(d.)	(e.)
Mag. carb.	300 Gm.	4 ℥	4 oz.
Eleosacch. of fennel	210 Gm.	2 ℥ 6 ʒ 1 ℈ 4 gr.	2 oz. 350 gr.
Rhubarb	90 Gm.	1 ℥ 1 ʒ 1 ℈ 16 gr.	1 oz. 87½ gr.

9. Recipe for polishing paste:—oxalic acid, 1 part; jewelers' rouge, 16 parts; rotten stone, 20 parts; palm oil, 59 parts; petrolatum, 4 parts. (a.) Calculate formula for 1 lb.; (b.) for 1 Kg.; (c.) for 12 oz.; (d.) for 400 Gm.

CHAPTER V.

Proportions.

To solve the problem—If 20 lb. of tartaric acid cost $7, how much will 32 lb. cost?—we reason as follows :—1 lb. of acid will cost $7.00 ÷ 20 = $.35 ; and 32 lb. will cost 32 times as much as 1 lb., hence $.35 × 32 = $11.20.

We may arrive at the same answer by an operation based upon a different line of reasoning, thus :—Price and quantity in this problem bear such a relationship to each other that they increase and decrease in the ratio. If, for instance, the quantity is doubled, is raised to 40 lb., the price must be doubled likewise, must be raised to $14.00. Notice that the increase is not dollar per pound, *but at the same rate* in case of the dollars as in case of the pounds. If the quantity is reduced to one-fourth, to 5 lb., the price becomes $7.00 ÷ 4 = $1.75. Then if we can find the ratio of 20 lb. to 32 lb., we have also the ratio of $7.00 to the answer sought.

When this definite relationship exists between values— when they increase and decrease in the same ratio—the values are said to be proportional to each other. Thus quantities and prices are proportional.

The statement that 20 lb. bears the same relation to 32 lb. as $7.00 bears to $11.20, is called a statement of a proportion. The statement may be more concise as follows.—

20 lb. is to 32 lb., as $7.00 is to $11.20.

For *is to*, it is customary to use the sign of ratio, the colon [:] ; and for *as*, the sign of proportion, the double colon [::]. Thus—

  20 lb. : 32 lb :: $7.00 : $11.20.
      is to   as   is to

Each one of the members of the proportion is called a term. Terms are numbered from left to right. Thus in the preceding example 20 lb. is the *first* term, 32 lb., the *second* term, $7.00, the *third* term, and $11.20, the *fourth.*

The first two terms constitute the *first couplet,* and the last two, the *second couplet.*

The first and last terms are called the *extremes*; the second and third, being in the middle, are called the *means*.

1st couplet		2nd couplet	
20 lb. :	32 lb. : :	$7.00 :	$11.20
1st term	2nd term	3d term	4th term

means

extremes

It will be seen that the product obtained by multiplying the two means, and the product obtained by multiplying the two extremes are the same.

$$20 \times 11.20 = 224.00$$
$$32 \times 7.00 = 224.00$$

It follows that the product of the extremes divided by either mean will give the other mean. And the product of the means divided by either extreme will give the other extreme.

$$224 \div 20 = 11.20;\ 224 \div 11.20 = 20$$
$$224 \div 32 = 7.00;\ 224 \div 7.00 = 32$$

Hence if three terms are known, the fourth one may be calculated.

The missing term may be any one of the four, as follows:

1. If 20 lb. of acid cost $7.00, how many lb. of acid may be bought for $11.20?

2. If 32 lb. cost $11.20, how many lb. could be bought for $7.00?

3. If 20 lb. cost $7.00, how much would 32 lb. cost?

4. If 32 lb. cost $11.20, how much would 20 lb. cost?

The preceding four problems may be stated thus:

1.	x	:	20 lb.	::	$11.20	:	$7.00
2.	32 lb.	:	x	::	$11.20	:	$7.00
3.	32 lb.	:	20 lb.	::	x	:	$7.00
4.	32 lb.	:	20 lb.	::	$11.20	:	x

And solved thus:

1 and 4.   Multiply the two means, and divide by the given extreme.

2 and 3.   Multiply the two extremes, and divide by the given mean.

It is, however, simpler and less apt to lead to error, if the proportion be always so stated that the missing term is the fourth.

This can be done by applying the following rules:

1.   Let the 3d term be that number which expresses the same kind of value as will be expressed by the answer sought.

2.   Then decide whether the answer sought is to be greated or smaller than this 3d term.   If greater, place the greater of the two remaining terms as the 2nd term; if smaller, place the smaller of the two remaining terms as the second.

3.   The remaining known term place as the first.

Note.—The 1st and 2nd terms must be in the same unit of value, in order that the ratio of the abstract numbers may also be the ratio of the denominate numbers.

Since the missing term is one of the extremes, it is obtained by multiplying the two means—the 2nd term and the 3d—and dividing the product by the 1st term*.

Note.—The answer will be in the same unit as the 3d term.   If it is to be in a different unit it must subsequently be reduced to that unit.

Problem.—If 437.5 gr. (1 oz.) of phenacetine cost 95c. how much will 120 gr. (2 5) cost?

Solution.—The three known terms are—95c, 437.5 gr., 120 gr.

The answer will express cost. i. e., money-value.   Therefore the known term expressing cost should be the third term:

$$:\qquad\qquad ::\qquad 95c\quad :\quad x\qquad (Answer.)$$

Since the quantity for which the cost is to be found is less than the quantity for which the price is given, the answer will be smaller than the third term.   Hence the smaller of the two remaining terms is to be the second:

$$:\qquad 120\ gr.\qquad ::\qquad 95c\quad :\quad x$$

As but one known term remains unplaced, this must be the first:

*This is identical with dividing the known term of the second couplet by the ratio of the 1st term to the 2nd.

            437.5 gr.   :   120 gr.   : :   95c   :   x

The 1st and 2d terms may now be treated as abstract numbers:

            95c × 120 = 11400c
            11400c ÷ 437.5 = 26c.   (Answer.)*

Solving the problem by analysis, we would reason thus : —if 437.5 gr. cost 95c, 1 gr. will cost 95c ÷ 437.5 ; and 120 gr. will cost 120 times as much as 1 gr. In this case the division is carried out first, and the quotient is multiplied, while in the proportion the multiplication is carried out first and the division last. One of the fundamental rules of arithmetic is that multiplication and division may be carried out in any order. So a proportion could be completed by dividing the first term into the second or third, and then multiplying the remaining known term by the quotient. But it is preferable to carry division out last—not only in proportions, but in all problems—for the reason that the quotient may be burdened with an interminate decimal, the rounding off of which occasions an error, an error that a subsequent multiplication would magnify.

Problems.

1. If cocaine costs $6.50 an oz., how much will 3 ʒ cost ?

Solution.—The three known terms are: $6.50, 1 oz., ond 3 ʒ. The answer is to express cost. Hence—

                :   : : $6.50   :   x

The 1st and 2d terms must be in the same unit. In this problem the 1 oz. and the 3 ʒ are best reduced to gr.

1 oz. = 437.5 gr., and 3 ʒ = 180 gr. [If the cost were known per ʒ, it would be simpler to reduce to ʒ.]

---

*Cancellation.

The figuring may frequently be lessened by ,cancellation. That is, by dividing the first term by a certain number, and then one of the other terms by the same number, which process in no way* changes the ratios.

Example,—   3   91
                   270   :   819   : :   350   :   x

The first term and also the third may be divided by 10 by cancelling the ciphers. Then the first term and the second may each be divided by 9. The work has now been simplified to 91 × 35 ÷ 3.

In proportions stated so that the unknown term is the fourth, the second and third terms are multiplied, one with the other, and hence cannot be cancelled against each other.

The quantity for which the cost is to be found is smaller than the quantity for which cost is given. Hence the answer will be smaller—

      437.5 gr.   :   180 gr.   : : $6.50   : x

  $6.50 × 180 = $1,170.00; $1,170.00 ÷ 437.5 = $2.67.

2. (a.) If cocaine costs $6.50 an oz., how much will 2 ʒ 1 ϶ 5 gr. cost? (b.) How much will 2 Gm. cost? (c.) How much will 3.256 Gm. cost? Ans. (c.) 74c.

3. (a.) If chloral hydrate costs $1.30 a lb., how much will 1 ʒ cost? (b.) How much will 10.560 Gm. cost?

4. (a.) If cream of tartar costs 60c per Kg. (Kilo.), how much will 1 lb. cost? (b.) How much will 1 ʒ cost? (c.) How much will 2¾ oz. cost? (d.) How much will 2 ʒ 2 ʒ 2 ϶ 2 gr. cost? Ans. (a.) 27c.

5. If homatropine costs $6.00 a Gm., how many gr. can be bought for $1.75?

Remarks.—The answer is to express quantity; hence 1 Gm. is the 3d term. The answer will be in Gm., and must be reduced to gr.

6. If homatropine costs $6.00 a Gm., how much would 2 gr. cost? Ans. Nearly 78c.

7. If 15 gr. of heroin cost 18c, how much is 1 oz. worth?

8. (a.) If alcohol costs $2.40 a gallon, how much does a Liter cost? (b.) How much would 225 c.c. cost? (c.) How much would 2 O. 6 f ʒ cost? (d.) How much can be bought for $100?

9. Glycerin cost 23c per lb. Its sp. gr. is 1.25. How much does it cost a Liter?

    Solution.—   1 L. = 1000 c.c.;

              1000 × 1.25 (sp. gr.) = 1250 Gm.

              1 lb. = 453.6 Gm.

    Then 453.6 Gm.   :   1250 Gm.   : :   23c   :   x   67.8

Note.—Quantity is proportional to price; and the quantity may be expressed in weight or volume, and in any unit of these, provided the 1st and 2d terms are in the same unit. So this and similar problems may be solved in several different ways.

10. Oil of lemon costs $1.25 a lb., and has a sp. gr. of .858. How much does it cost per f ʒ? Ans. 7c.

11. (a.) Mercury costs $1.50 per Kg. Taking its sp.

gr. as 13.5, how much would 4 f ℥ cost? (b.) How much would 12 c.c. cost? (c.) How much would 2 f ℥ 45 ℳ cost?

12. Alcohol costs $2.40 a gal., and has a sp. gr. of .82. How much does it cost per lb.? Ans. 35.7c.

13. Castor oil costs 14c. a lb., and has a sp. gr. of .95. How much does it cost a gal? Ans. $1.10.

14. Chloroform costs 60c. a lb., and has a sp. gr. of 1.49. How many f ℥ can be bought for 75c? Ans. 12.88 f. ℥.

15. If 4 Gm. of mustard will make 60 square centimeters of mustard paper (plaster), how much mustard should be spread on a plaster 3 in. by 4 in.?

Solution.— 3 in. by 4 in. = 7.6 cm. by 10.2 cm.; and 7.6 cm. × 10.2 cm. = 77.52 sq. cm.

Then 60 sq. cm. : 77.52 sq. cm. : : 4 Gm. : x (5.166 Gm.)

16. If 1 gal. of paint costs $1.35, and will cover 500 sq. ft., what would be the cost of 3 coats for a house 18 ft. high 30 ft. broad, and 45 ft. long?

Remarks.—The relationship between price and quantity, or between quantity of paint and amount of surface to cover, as in problem 16, is clearly seen, and that these values are proportional is quite obvious. But in many pharmaceutical problems the relationship is not so apparent, or, may appear to exist when it does not. In the appendix is given a list of proportional values, which list should be frequently consulted.

Certain values bear such a relationship to each other that one increases in the some ratio in which the other decreases. Values proportional in this sense are said to be inversely proportional. See Chapter VII.

TRADE DISCOUNT.

Problems involving interest, profit and loss, premiums, discount, as well as all other percentage problems, may be solved without the use of specific rules, if the general directions for stating proportions are observed.

It should be remembered, however, that if several discounts are given, the second is based not upon the regular selling price, but upon the price obtained by deducting the first discount; that the third is based upon the price obtained by deducting the first and second discounts; etc.

Problem.—Certain apparatus is quoted at $120.00 per gross, with 40%, and 10% off, and an additional discount of 3% for cash. What is the net cost?

Solution.— 40% of $120.00 = $48.00; $120.00 minus $48.00 =$72.00.

10% of $72.00 = $7.20; $72.00 minus $7.20 = $64.80

3% of $64.80 = $1.94; $64.80 minus $1.94 = $62.86 (Ans.)

CHAPTER VI.

PERCENTAGE PROBLEMS.

Percentage—abbreviated percent., and indicated by the symbol %—means parts per 100 parts.

Opium, said to contain 14% of morphine, contains 14 parts of the latter to 86 parts of other constituents, making 100 parts in all.

The amount of a constituent in a drug, the amount of component in a mixture or in a preparation, the amount of dissolved substance in a solution,—all these amounts are conveniently expressed in percentages; that is, they are conveniently adjusted to the scale of 100*.

This being true, problems involving percentages are of frequent occurrence in every-day work.

In such problems the following factors come into play:

1. The amount of drug, mixture, preparation, or solution, or whatever is to represent the 100 parts.

2. The amount of constituent or ingredient.

3. The amount of constituent or ingredient as expressed in percentage.

4. The amount of drug, mixture, etc., expressed in percentage. This is always 100, and is never sought as an answer.

5. The amount of diluent or solvent.

For sake of brevity let us designate drug, mixture, preparation, or solution by M, standing for mixture; constituent or ingredient by C, standing for constituent; percentage by its customary symbol, %; and diluent or solvent by D.

In percentage problems there are four cases possible: (1) M may be sought, the other factors being known; (2)

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*In order that comparisons may be readily made—made by inspection—such data should be reduced to *some* common standard or scale; and the number 100 is selected, rather than 12, 144, or any other number, for arithmetical reasons.

C may be sought; (3) % may be the element to be calculated; (4) the amount of diluent or solvent may be sought.

It should be remembered that percentages in pharmaceutical or chemical problems refer to parts *by weight,* unless the contrary is expressly stated. Now, if percentages stand for parts by weight, they are proportional to weights of M and of C, and any one of the first three factors—M, C, or %—may be calculated by proportion.

D is the difference between C and M, and is found by subtracting C from M. See page 79.

Examples.

1. Suppose that 6 Gm. of opium on analysis are found to contain .585 Gm. of morphine, and the morphine-strength of the opium is to be expressed in percentage.

Solution:—

The three known terms are:—6 Gm. (amount of drug = M), .585 Gm. (amount of morphine, i. e., constituent = C), 100 per cent. (per cent of M)*.

The missing term is per cent. of C.

Since the answer is to be in per cent., the known per cent., 100 per cent. (M is always assumed to be 100 per cent.), must be the third term.

$$. \quad : \qquad :: \quad 100 \text{ per cent.} \quad : \quad x$$

The answer is to be smaller than 100 per cent., because the amount of C. (.585 Gm.) is smaller than the amount of M (6 Gm.). Or, to generalize, the per cent. of C must always be less than 100, because a part is less than the whole. Therefore the smaller of the two remaining known terms is the second, and the larger, the first.

$$6 \text{ Gm.} \quad : \quad .585 \text{ Gm.} \quad :: \quad 100 \text{ per cent} \quad : \quad x$$
$$x = 9.75 \text{ per cent.}$$

2. How much morphine is present in 60 Gm. of opium having a morphine-strength of 12% ?

The three known terms are:— 60 Gm. (amount of M), 12 per cent. (per cent. of C), and 100 per cent. (per cent. of M).

---

*Remember that M always stands for the medicinal substance or preparation in its totality. So in this and the immediately succeeding problems it stands for opium, and not for morphine, although the latter word begins with *m*. The choice of drug and constituent might *appear* unfortunate; but the selection of a constituent with a name beginning with *m* was premeditated, the object being to point out that the symbols M and C are general, and have no relationship to the names of specific drugs, or of preparations, or of constituents.

The answer is to express weight. Therefore—

$$: \qquad :: \quad 60 \text{ Gm.} \quad : \quad x$$

The answer is to be smaller than 60 Gm., because 12 per cent. is less than 100 per cent. And because C, the part must weigh less than M, the whole.

Then the smaller remaining term (12 per cent.) must be the second. Thus—

$$100 \text{ per cent} \quad : \quad 12 \text{ per cent} \quad :: \quad 60 \text{ Gm.} \quad : \quad x$$
$$x = 7.2 \text{ Gm.}$$

3. If a certain opium has a morphine-strength of 14%, how much of the opium would contain just 5 Gm. of morphine?

The known terms are:— 100 per cent. (per cent. of M), 14 per cent. (per cent. of C), and 5 Gm. (wt. of C).

The term sought is wt. of M.

Since the answer is to be in weight, the known weight is the third term.

$$: \qquad :: \quad 5 \text{ Gm.} \quad : \quad x$$

The answer is to be greater, because 100 per cent, is greater than 14 per cent. and because the whole must be greater than the part. Hence—

$$14 \text{ per cent.} \quad : \quad 100 \text{ per cent.} \quad :: \quad 5 \text{ Gm.} \quad : \quad x$$
$$x = 35.714 \text{ Gm.}$$

While the rules on page 69 for stating proportions are always applicable, and cannot mislead, it is well to know that in percentage proportions correctly stated, M and C alternate; that is, the term giving % of M and the one giving weight of M are never side by side, but have another term between them,—which is true likewise, for the two terms giving respectively weight and % of C.

Observe the three proportions just given.

1.   6 Gm.   :   .585 Gm.   : :   100%   :   (x) 9.75%
    wt. of M.   wt. of C.   % of M.   % of C.

2.   100% : 12%   : : 60 Gm.   : . (x) 7.2 Gm.
     % of M.   % of C   wt. of M.   wt of C

3.   14% : 100%   : : 5 Gm.   : (x) 35.714 Gm.
     % of C   % of M   wt. of C   wt. of M..

N. B.—A similar alternation occurs in all proportions in which the two values are *directly* proportional; if they are inversely proportional [see chapter VIII] the alternation does not occur.

Oher Arithmetical Processes.

Problem 1 may be solved also by reasoning as follows: If 6 Gm. of opium contain .585 Gm. of morphine, 1 Gm. of opium will contain .585 Gm. ÷ 6 = .0975 Gm.; and 100 Gm. will contain 100 times as much as 1 Gm., hence [.0975 Gm × 100 =] 9.75 Gm.

Consequently the answer is, 9.75 per cent.

Formulating this we have—

$$\% = (C \div M) \times 100 \quad \text{or,} \quad \% = \frac{C \times 100}{M}$$

Problem 2 is solved as follows: If the morphine strength of the opium is 12 per cent., each 100 Gm. of the latter contain 12 Gm. of morphine, and 1 Gm. of opium contains 12 Gm. ÷ 100 = .12 Gm. Then 60 Gm. contain 60 times as much as 1 Gm., that is [.12 Gm. × 60 =], 7.2 Gm.

Expressing the above process in a formula, we have—

$$C = (\% \div 100) \times M \quad \text{or,} \quad C = \frac{\% \times M}{100}$$

Problem 3: If the morphine-strength of the opium is 14 per cent., 100 Gm. of the latter contain 14 Gm. of morphine. Then 1 Gm. of morphine will be contained in [100 Gm. ÷ 14 Gm. =] 7.142S Gm. of opium; and 5 Gm. of morphine will be contained in 7.142S Gm. × 5 = 35.714 Gm.

This expressed in a formula gives:

$$M = (100 \div \%) \times C \quad \text{or,} \quad M = \frac{100 \times C}{\%}$$

The same result may be obtained as follows: In 100 Gm. of opium there are 14 Gm. of morphine. In 1 Gm. of opium there are

14 Gm. ÷ 100 = .14 Gm. of morphine. Then the answer will be: as many Gm. of opium as .14 Gm. is contained in 5 Gm. = 35.714 Gm.

Formula—

M = C ÷ % ÷ 100.

Since dividing the divisor is the same as multiplying the dividend,

$$\frac{100 \times C}{\%} = C \div \% \div 100,$$

and the two processes must give the same answer;—must both be correct.

Advice to Students.

The formulas in the preceding paragraphs should not be memorized, and followed blindly. Students who cannot solve percentage problems by a process of reasoning, are strongly advised to avoid all formulas and rules (which are usually remembered imperfectly), and to solve all such problems by proportion. The principles underlying proportions are soon mastered by the average students; and by the exceptional ones, who are absolutely unmathematical, the process may be followed empirically without danger of error, as, in proportions, no matter what the case—no matter which factor is missing—the rules to be followed are the same. (See page 69).

Problems.

4. A certain drug contains 17% of soluble matter, hence will yield 17% of extract. How much extract could be obtained from 500 Gm. of the drug? Ans. 85 Gm.

5. How many lbs. of the same drug would be required to make 5 lbs. of extract? 29 1/7 lb., or 29.41 lb.

6. What is the percent. of extractable matter in a certain licorice root, 500 Gm. of which yield 90 Gm. of extract?

7. Diluted hydrocyanic acid, U. S. P., contains 2% of absolute hydrocyanic acid (HCN), the remainder being water. How much absolute acid in 450 Gm.? Ans. 9 Gm.

8. Official nitric acid contains 68% of absolute nitric

acid (HNO_3), the remaining 32% being water. How many gr. of absolute HNO_3 in 400 gr.? Ans. 272 gr.

9. How many Gm. of iodine in 300 Gm. of a 5% solution?

10. How much iodine should be weighed out to make 1 Kg. of a 5 % solution?

11.. How many Gm. of 5% soda solution can be made from 400 Gm. of soda?

12. What is the percentage strength of a solution of homatropine made by dissolving 15 gr. in enough water to make 400 gr.? Ans. 3.75%.

13. What is the percentage strength of a solution of mercuric chloride made by dissolving 60 gr. of the latter in enough water to make 5,000 gr.?

14. What is the percentage strength of a solution of sodium chloride made by dissolving 65 gr. of the salt in 400 gr. of water?

Solution.— 65 gr. in 400 gr. would make 465 gr. of solution. The three known terms are: [400 + 65 =] 465 gr., 65 gr., 100 per cent. Percentage is asked for. Hence—

$$:   ::   100\%   x.$$

The answer is to be less than 100%. Hence—

$$465 \text{ gr. } : 65 \text{ gr. } :: 100\% : (x) 13.9\%$$

15. What is the percentage strength of a solution of carbolic acid in glycerin made by mixing 350 Gm. of the latter with 200 Gm. of the acid?

16. Boric acid is soluble in 25.6 parts of water. What is the percentage strength of a saturated solution?

Solution.— 1 part of acid + 25.6 parts of water = 26.6 parts of solution. Then 26.6 parts : 1 part :: 100% : x (3.76%).

17. Potassium chlorate is soluble in 16.7 parts of water. What is the per cent. strength of a saturated solution?

18. One part of water will dissolve 1.33⅓ parts of potassium iodide. What is the per cent. strength of a saturated solution? Ans. 57⅐ %.

19. One part of water will dissolve $\frac{1}{16}$ part of po-

tassium permanganate. What is the per cent. strength of a saturated solution? Ans. 5.88%.

20. What percentage of sugar in a syrup made from 1 lb. of sugar and ½ lb. of water?

Calculating Amount of Diluent or Solvent.

To make 100 Gm. of a 15% solution of salt we may proceed in two ways: we may weigh out 15 Gm. of salt, and then add enough water to bring the total weight to 100 Gm.; or, we may add to the 15 Gm. of salt 85 Gm. of water, previously weighed. In the first method there is a possibility of adding too much water; and as solution begins at once, the excess of water cannot be removed without removing some salt also. For this reason the second method is preferred.

21. How many lbs. of sugar, and how many of water, are required to make 12 lbs. of syrup having a sugar-content of 65%?

Solution.—   100 per cent.   :   65 per cent.   : :   12   lbs.   :   x
                                            x = 7.8 lbs. (wt. of sugar).

Then   12 lbs. — 7.8 lbs. = 4.2 lbs. (wt. of water).

22. In how many Gm. of water must 15 Gm. of cocaine hydrochloride be dissolved to make a 4% solution?

Solution.—   4 per cent.   :   100 per cent.   ::   15 Gm.   :   x
                                            x = 375 Gm. (wt. of solution to be made).

Then 375 Gm. (wt. of solution) minus 15 Gm. (wt. of cocaine) = 360 Gm. (wt. of water).

23. How many Gm. of magnesium sulphate, and how many Gm. of water, are required to make 600 Gm. of 28% solution? Ans. 168 Gm. Mag. Sulph. and 432 Gm. water.

24. How many oz. of carbolic acid, and how many of petrolatum, must be used to make 32 oz. of carbolated petrolatum containing 3% of carbolic acid?

25. How many Gm. of water must be used to dissolve 4 Gm. of mercuric chloride to make a $\frac{1}{10}$ % solution?

26. A certain nasal spray consists of liquid petrolatum, with 6% of menthol, 5% of eucalyptol, and 2% of thymol. How much must be used of each of the ingredients to make 150 Gm?

Solution.—
$$100\% \ : \ 6\% \ :: \ 150 \text{ Gm.} \ : \ x$$
$$x = 9 \text{ Gm. (am't of menthol).}$$

$$100\% \ : \ 5\% \ :: \ 150 \text{ Gm.} \ : \ x$$
$$x = 7.5 \text{ Gm. (am't of eucalyptol).}$$

$$100\% \ : \ 2\% \ :: \ 150 \text{ Gm.} \ : \ x$$
$$x = 3 \text{ Gm. (am't of thymol).}$$

Then 9 Gm. + 7.5 Gm. + 3 Gm. = 19.5 Gm. (am't of active ingredients) ;

And 150 Gm. (am't of spray) — 19.5 Gm. (am't of active ingredients) = 130.5 Gm. (am't of liquid petrolatum).

27. ℞ Iodoform   gr. xxx
        Boric acid   ℥ j
        Naphthalin   ℥ j

Make a fine powder, and flavor with 2% of oil of bergamot.

How much of the latter must be used? Ans. 3 gr.

28. How much oil, acacia and water are required to make the nucleus of 120 c.c. of a 40% emulsion. Sp. gr. may be ignored.

Solution.—By the continental method the nucleus is made of 4 parts of oil, 1 part of acacia, and 2 parts of water.

    40 per cent of 120 c.c. = 48 c.c. (amount of oil).
    Then if   44 parts = 48 c.c. (amount of oil),
                     2 parts = 24 c.c. (amount of water),
                     1 part = 12 Gm. (amount of acacia).

This nucleus is then to be diluted to 120 c.c., making a 40 per cent. emulsion.

Percentage Problems Involving Conversion from One System of Weight to Another.

29. How many Gm. of 4% solution can be made with 1 oz. of cocaine hydrochloride? Ans. 708.75 Gm.

30. What is the per cent. strength of a morphine sulphate solution made by dissolving ⅛ oz. in enough water to make 100 Gm.? Ans. 3.543%.

31. To make 5 lbs. of 5% solution of soda, how many Gm. of the latter must be used?

32. How many Gm. of 2% atropine sulphate solution can be made with 1 ℥ 1 ℈ 10 gr.?

PROBLEMS INVOLVING ALSO REDUCTION OF VOLUMES TO WEIGHTS, OR WEIGHTS TO VOLUMES.

Since in these problems—and always when the contrary is not expressly stated—percentages stand for parts by weight, they are proportional to weights, *but not to volumes. If quantities* [of M or of C] *are given in volumes, these must be reduced to weights before employing the quantities as terms in proportions.* If the answers (4th terms of) these proportions represent quantities, these will be in weight—not in volume. So a conversion to volume must follow whenever the answer is to express volume.

33. Official nitric acid has a sp. gr. of 1.414, and contains 68% of absolute acid. How many Gm. of abs. acid in 2 L. of the official acid?

Solution.— 2 L. = 2000 c.c.

2000 × 1.414 (sp. gr.) = 2828. Hence 2000 c.c. = 2828 Gm.
Then 100% : 68% :: 2828 Gm. : x
x = 1923.04 Gm. (wt. of abs. acid).

34. Official solution of potassa has a sp. gr. of 1.036, and contains 5% of potassa. How many f℥ of solution could be made from 20 Gm. of potassa?

Solution.— 5% : 100% :: 20 Gm. : x
x = 400 Gm. (weight of solution).
400 ÷ 1.036 (sp. gr.) = 386.1. (vol. in c.c.)
386.1 ÷ 29.57 (c.c. in 1 f℥) = 13.057 f℥ or 13 f℥ 27 ♏

35. Syrup contains 85 Gm. of sugar in 100 c.c., and has a sp. gr. of 1.317. What per cent. of sugar does it contain?

Solution.—The sp. gr. being 1.317, 100 c.c. of syrup weigh 131.7 Gm.

Then— 131.7 Gm. :   85 Gm.   ::   100%   : x
$$x = 64.54\%$$

36. Stronger ammonia water has a sp. gr. of .901, and contains 28% of ammonia. How many Gm. of the latter in 1 pint of the stronger water? Ans. 119.358 Gm.

37. Official sulphuric acid has a sp. gr. of 1.835, and contains 92.5% of absolute acid. (a.) How many gr. of absolute acid in 1 f ℥ of official acid? (b.) How many Gm. of abs. acid in 2 L. of official acid? Ans. (a.) 773.5 gr.

38.. Official solution of ferric citrate has a sp. gr. of 1.25 ; and 1 L. yields 531.25 Gm. of ferric citrate (scale salt). What per cent. of ferric citrate in the solution?

39. In a certain chemical reaction 5 Gm. of absolute hydrochloric acid (HCl) is required. To supply it how many c.c. of official acid (sp. gr., 1.163, absolute-acid-content, 31.9%) must be used? Ans. 13.47 c.c.

40. 30 c.c. of ether, sp. gr., .725, is dissolved in enough alcohol to make 100 c.c. of solution, the latter having a sp. gr. of .8. What per cent. of ether (by weight) in the preparation?

41. Lead subacetate solution has a sp. gr. of 1.195, and contains 25% of lead subacetate. On diluting 3 c.c. of this solution to 100 c.c., diluted solution of lead subacetate (U. S. P.) is obtained. How much lead subacetate does the latter solution contain in each f ℥?

Solution.—1 f ℥ = 29.57 c.c. If 100 c.c. of the diluted solution contain 3 c.c. of the strong solution, 1 c.c of the diluted solution will contain 3 c.c. ÷ 100 = .03 c.c. of the strong; and 29.57 c.c. of the diluted solution will contain .03 c.c. × 29.57. = .8871 c.c. of the strong solution. The sp. gr. of the latter being 1.195, the .8871 c.c. weighs [.8871 × 1.195 =] 1.06 Gm. Of this 25% is lead subacetate. Then—

100% : 25% :: 1.06 Gm. : (x) .265 Gm.

42. Solution of ferric sulphate has a sp. gr. of 1.32, and contains 28.7% of ferric sulphate. How many gr. of

ferric sulphate in 1 f℥ of a diluted solution, containing 20
c.c. of the official solution in 100 c.c.? Ans. 34.5 gr.

Volume Percentage.

A volume percentage solution is one having in 100
volumes a definite number of volumes of constituent, the
latter necessarily being a liquid. Thus, alcohol, U. S., con-
tains 94% by volume of absolute ethyl hydroxide, the re-
maining 6% by volume being water. Diluted alcohol, U. S.,
contains 48.6% by volume of ethyl hydroxide, and 51.4% by
volume of water.

Notice that it is expressly stated that the percentage
is by volume. When such a statement is absent, weight
percentage is always understood.

Since percentages in volume percentage stand for vol-
umes, they are proportional to volumes just as weight per-
centages are proportional to weights. In other words, vol-
ume percentages are proportional to L., c.c., f ℥, ℳ, etc.,
but not to weight units.

Problems.

44. In 1 gallon of alcohol, containing 94% by vol. of
ethyl hydroxide, there are how many f ℥ of the latter? Ans.
120.3 f ℥.

45. In 5 L. of diluted alcohol, containing 48.6% by
vol. of ethyl hydroxide, there are how many c.c. of the
latter?

46. A certain alcohol contains 6 O. 8 f ℥ of abs. ethyl
hydroxide in each gallon. What % by vol. of ethyl hydrox-
ide does the alcohol contain? Ans. 81.25% by vol.

47. A certain menstruum is to contain 15% by volume
of glycerin. How much of the latter should a pint con-
tain? Ans. 2 f ℥ 3 f ℥ 12 ℳ.

Calculating Volume Percentage to Weight Percent-
age and Vice Versa.

If the sp. gr. of the constituent is known, and also the
sp. gr. of the solution, volume percentage may be calculated
to weight percentage,—and vice versa.

48.   Alcohol, U. S., containing 94% by volume of ethyl hydroxide contains what % by weight?

Solution.—The sp. gr. of the alcohol [solution] is given as .82; that of ethyl hydroxide [constituent] as .79. If the sp. gr. of the alcohol is .82, 100 c.c. of it weigh 82 Gm. If the sp. gr. of the ethyl hydroxide is .79,   94 c.c. of it would weigh [94 × .79 =] 74.26 Gm.

Then—
82 Gm. : 74.26 Gm.   ::   100% : x 90.56%
wt. of M : wt. of C   ::   % by wt. of M : % by wt. of C

49.   Alcohol is 91% strong by weight.   Calculate strength in volume percentage.

Solution.— 100 Gm. of alcohol = 100 ÷ .82 = 121.9 c.c.
            91 Gm. of ethyl hydroxide = 91 ÷ .79 = 115 c.c.

Then 121.9 c.c. : 115 c.c.   ::   100% : (x) 94 + %
      vol. of M : vol. of C.   ::   vol. % of M. : vol. % of C.

50.   The sp. gr. of ethyl hydroxide being .79, what is the wt. per cent. strength of an alcohol of 66% by vol., and having a sp. gr. of .9?

51.   An alcohol has a sp. gr. of .8721, and contains 70% by wt. of ethyl hydroxide [sp. gr. .79]. What % by vol. of the latter does it contain?

[See Squibb's alcohol table, U. S. P.]

Note.—By the Internal Revenue Office strength of alcoholic liquids is expressed by degrees proof. An alcoholic liquid containing 50 per cent. by vol. of absolute ethyl hydroxide is said to be 100 proof. Common alcohol, 94 per cent. by vol. strong, is said therefore to be 188 proof. In short—degrees proof ÷ 2 = strength in per cent. by vol.; and per cent. by vol. × 2 = degree proof.

52.   What is the alcohol strength of brandy marked 110 proof?

Solution.— 110 ÷ 2 = 55% by vol.

To Calculate Amount of Constituent When the Sp. Gr. of Solution is Unknown.

Percentage, unless the contrary is expressly stated, re-
fers to parts by weight. If the amount of constituent is to
be calculated from the amount of solution, the weight of
the latter must be known,—or must be calculated from the
volume and the sp. gr., as in the problems on page 81.

In practice, however, the pharmacist is often called
upon to dispense a definite volume of a solution of specified
percentage strength but of unknown sp. gr.

For instance, 1 f ʒ of a 4 % solution of cocaine hydro-
chloride may be wanted.

Now, the error due to the assumption that the sp. gr.
of such a low-strength solution is 1.000, would be very
slight, and would be considered negligible by most physi-
cians. But the doctrine of permissible inaccuracy is a
dangerous one; and the student is not advised to take
"short cuts" which in the least affect the strength of a
medicinal preparation. A solution of *exact* strength can be
made as follows:

*Base the Calculation of Amount of Constituent upon
the Amount of Solvent and of the Latter use as Much as
Product Desired.*

The constituent will augment the volume somewhat;
and if an exact volume is wanted, this may be measured out,
and the excess either saved or rejected—according to its
stability, commercial value, etc. To illustrate, let us revert
to the problem just given, calling for 1 f ʒ of a 4% solution.

Calculation.—Since the solution is 4 per cent. strong, the solvent
represents 96 per cent.; and if we take 4 parts by weight of con-
stituent as often as we have 96 parts by weight of solvent, our
finished product will contain 4 parts in 100 parts, i. e., will be ex-
actly 4 per cent. strong.

Accordingly, 96% : 4%   ::   455.7 gr.(wt. 1 fʒ water) : x

$$x = 18.98 \text{ gr.}$$

Thus by measuring out 1 f ℥ of water, and dissolving in it 18.98 gr. (19 gr.) of constituent, we get a trifle (about 9 ♏) over 1 f ℥ of solution exactly 4%   strong.

The superiority of this method over that of making a certain weight of solution (say 500 gr.) lies in this that measuring is less tedious than weighing.

Problem.—A physician orders 120 c.c. of 2% solution of mercuric chloride. How can the order be filled?

Calculation.—Let 120 c.c. represent 98%. Since 120 c.c. of water weigh 120 Gm., we have—

    98% : 2% :: 120 Gm. : x (2.449 Gm.)

Accordingly we dissolve 2.449 Gm. in 120 c.c. If precisely 120 c.c. of product is to be dispensed, this volume may be measured out and the excess, which represent no commercial value, may be rejected.

Problems.

How much solvent, and how much constituents should be used to fill the following orders:

53.   20 c.c. of 5% solution of apomorphine hydrochlor.

54.   60 c.c. of 6% solution of cocaine hydrochloride.

55.   1 L. of 10% solution of camphor in cotton seed oil, the latter having a sp. gr. of .92. Ans. 102.22 Gm.

56.   2 f ℥ 5% solution of iodine in alcohol, sp. gr. of latter, .82.

Solution.— 2 f ℥ = 2 × 455.7 gr. × .82 = 747.3 gr.
        95 %   :   5 %   : :   747.3 gr. :   x (39.3 gr.)
Accordingly 39.3 gr. of iodine are dissolved in 2 f ℥ of alcohol.

57.   2 f ℥ of 4% solution of homatropine. Ans. 4¾ gr. of homatropine and 2 f ℥ of water.

58.   1 f ℥ of 20% solution of tannic acid in glycerin, sp. gr. of latter, 1.25. Ans. 142.38 gr. of tannic acid and 1 f ℥ of glycerin.

59.   How many gr. of each constituent should be used

to make 2 f ℥ of eye lotion containing ¼% of zinc sulphate,
⅓% of morphine sulphate, and 2% of boric acid?

Weight to Volume Solutions.

Percentage solutions, as has been stated, are construct-
ed on the scale of 100 weight-units. As liquid medicines
are administered by volume, both per mouth and hypoder-
mically, the dose calculations become simplified if the
strength of the liquid is expressed, not in per cent., but in
Gm. in 100 c.c., or in gr. in 100 ℳ. The strength of most
galenical preparations is expressed in this way. And most
physicians would prefer to have hypodermic solutions con-
structed on this plan, so that by simple division the volume
containing the desired dose of constituent may be calculated.

In case of metric units weight to volume solutions dif-
fer from the corresponding percentage solutions only as the
sp. gr. of the solution differs from 1.000. But in case of
apothecaries' units there is a further difference, due to the
fact that 1 ℳ of water weighs less than 1 gr., namely
about .95 gr.

In some locations much confusion has resulted from the
misapplication of the conventional percentage symbol (%),
this being used to express the strength of weight to volume
solutions. In other words, some physicians use the % sym-
bol, expecting the pharmacist to give it a special inter-
pretation.

To avoid the resulting confusion the writer suggests
that a new symbol, $\frac{w}{v}$, be adopted for weight to volume
solutions. In case of metric prescriptions the w would stand
for Gm., and the v for 100 c.c.; while in case of apothecaries'
units w would mean gr., and v, 100 ℳ. A 4 gr. to 100 ℳ
solution would accordingly be 4 $\frac{w}{v}$, and nothing would be
left to guess-work.

Problems.

60. How many gr. of atropine are required to make
1 f ℥ of a 4 $\frac{w}{v}$ solution?

7

Then 100 ♏   :   480 ♏   ::   4 gr. :   x (19.2 gr.)*

Or: If 100 ♏ of solution contain 4 gr. of constituent, [4 gr. ÷ 100
=] .04 gr. is the amount of constituent in each ♏; and .04 gr.
×480 = 19.2 gr., the amount in 480 ♏.

Problems.

61. How many gr. of cocaine hydrochloride are re-
quired to make 4 f ℥ of a 6 $\frac{w}{v}$ solution? Ans. 14.4 gr.

62. How many f ℥ of a 4 $\frac{w}{v}$ solution could be made
from 1 oz. of cocaine hydrochloride? Ans. 22 f ℥ 6 f ℨ 17 ♏ .

63. What would be the $\frac{w}{v}$ strength of a solution of
boric acid made by dissolving 1 oz. of the latter in enough
water to make 2 pints of solution? Ans. 2.84 $\frac{w}{v}$

Other Methods for Expression of Strength of Solutions.

To avoid fractions, the strength of very dilute solutions
is sometimes expressed in parts in 1000, in 2000, 5000, or
even in 10000.

The solution of mercuric chloride, used as an antiseptic
by surgeons, offers a case in point. As these solutions are
generally for external use, the parts referred to are parts
by weight.

But the sp. gr. of these very dilute solutions is so nearly
1.000, that 1 c.c. may be considered as equivalent to 1 Gm.
in all cases, and 1 f ℥ as equivalent to 455.7 gr.

Problems.

64. How many gr. of mercuric chloride are required
to make 1 lb. of a 1 in 1000 solution?

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*In $\frac{w}{v}$ solutions c. c. of solution are proportional to Gm. of constituent; and ♏
of solution to gr. of constituent.

65. How many Gm. are required to make 2 L. of a 1 in 3000 solution?

66. How many gr. are required to make 1 pint of a 1 in 1000 solution? Ans. 7.29 gr.

67. How many gr. of mercuric chloride are required to make 2 f ℥ of a solution, 1 f ℥ of which diluted to ½ pint would make a 1 gr. to 2000 ℳ solution?

Solution.—Since ½ pint = 64 f ℥, the solution should be 64 times as strong as a 1 gr. in 2000 ℳ solution, that is, it should be a 64 gr. in 2000 ℳ solution.

Then— 2000 ℳ : 960 ℳ :: 64 gr. : (x) 30.72 gr.

68. How many Gm. of mercuric chloride should be weighed out to make 120 c.c. of a solution 25 c.c. of which diluted to a L. would make a 1 Gm. in 3000 c.c. solution? Ans. 1.6 Gm.

CHAPTER VII.

CONCENTRATION AND DILUTION.

If 100 Gm. of a 10% salt solution is diluted to 200 Gm., that is, to double its original weight, the percentage of salt will thereby be reduced to 5%, that is, to one-half the original percentage. If the solution is diluted to four times its original weight, the percentage strength falls to one-fourth of the original percentage strength. If on the other hand the 10% salt solution is concentrated from 100 Gm. to 50 Gm. [the solvent being evaporated off without effecting loss of salt], the percentage strength is thereby doubled—becomes 20%. Thus it is seen that with the *amount* of constituent remaining unchanged, the percentage strength decreases in the same ratio in which the quantity of solution is increased, and increases in the same ratio in which the quantity of solution is decreased.

As quantity of solution and percentage strength change in the same ratio, these two values are proportional to each other; but as the change is in opposite directions, they are said to be *inversely* proportional. **However, the general rules for stating proportions, as given on page 69 are applicable to inverse proportions as well as to direct proportions.**

With the amount of constituent (C) remaining constant, the following factors come into consideration in concentration and dilution problems:

1. Initial amount of solution (or mixture, or preparation).

2. Amount after dilution or concentration.

3. Initial percentage strength of solution (or mixture, or preparation).

4. Percentage strength after dilution or concentration.

If any three of these factors are given, the fourth may be found by proportion.

If amount of diluent (to be added) is required, this is found by subtracting the initial amount of solution (or mixture, or preparation) from the amount after dilution.

N. B.—Since percentage is commonly weight percentage, the amounts must be in weight except when the percentage is expressly stated to be volume percentage, in which cases the amounts must be in volume.

Problems.

1. What is the % strength of a salt solution obtained by diluting 10 lb. of a 10% solution to 14 lb.?

Solution.—Percentage is asked for. Hence—

:   :: 10% : x

After dilution the strength will be less than 10%. Hence the smaller of the remaining terms is the second, and the larger the first:

14 lb. : 10 lb. :: 10% : (x) $7\frac{1}{7}$%

2. What is the % strength of a salt solution obtained by evaporating 10 lb. of a 10% solution to 8 lb.?

Solution.—Percentage is asked for. Hence—

:   :: 10% : x

After concentration the strength will be over 10%. Hence—

8 lb. : 10 lb. :: 10% : (x) $12\frac{1}{2}$%.

3. To what weight must 500 Gm. of 10% salt solution be evaporated in order to make a 16% solution?

Solution.—Weight is asked for; and after concentration the solution will weigh less than 500 Gm. Hence—

16% : 10% :: 500 Gm. : (x) 312.5 Gm.

4. How many Gm. of 10% nitric acid (the diluted nitric acid of the U. S. P.) can be made from 300 Gm. of nitric acid containing 68% of abs. acid? Ans. 2040 Gm.

5. How many lb. of acetic acid, 32% strong, are required to make 10 lb. of diluted acetic acid, which contains 6% of abs. acid? Ans. $1\frac{7}{8}$ lb.

6. What is the % strength of ammonia water obtained

by diluting 500 Gm. of stronger ammonia water, containing 28% of ammonia, to 1800 Gm.? Ans. 7 ⅞%.

7. In order to bring a certain extract of opium to the official morphine strength (18%) 1 lb. 4 oz. had to be evaporated to 14 oz. What was the morphine strength of the extract prior to the evaporation? Ans. 12.6%.

8. To what weight must 1 Kg. of alcohol, 91%, be diluted to make alcohol of 41% strength?*

9. How many Gm. of sulphuric acid, 70%, can be made from 4 lb. of acid of 92.5% strength?

N. B.—The two terms of a couplet must be in the same unit.

10. How many lb. of hydrochloric acid, 31.9%, are required to make 5 Kg. of 10% hydrochloric acid?

11. How many gallons of alcohol, 94% by vol., are required to make 25 L. of alcohol which is 50% strong by vol.? Ans. 3.512 gal.

12. To what weight must 600 c.c. of solution of sodium hydroxide (sp. gr., 1.437; strength, 40%) be diluted in order to make a 5% solution? Ans. 6897.6 Gm.

N. B.—Amount must be in weight for proportion.

13. What is the % strength of a diluted hydrochloric acid obtained by diluting 1 L. of hydrochloric acid (sp. gr., 1.163; strength, 31.9%) to 5 lb.? Ans. 16.38%.

14. Diluted hydrocyanic acid should contain 2% of abs. acid. To how many Gm. must 1 lb. 5 oz. 200 gr. of a 2.35% acid be diluted in order to reduce it to official strength —to 2%?

15. To how many f ℥ must 500 c.c. of alcohol (sp. gr., .82; strength, 91%) be diluted in order to make 58% alcohol having a sp. gr. of .9? (See next page.)

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*The pharmacopoeia gives this rule for diluting alcohol:

Designate the weight-percentage of the stronger alcohol by **W**, and the desired strength by *w*.

Rule.—Mix *w* parts by weight of the stronger alcohol with water to make **W** parts by weight of the product.

To anyone familiar with the general directions for stating proportions, this rule is superfluous.

Suggestion.—Convert 500 c.c. to Gm.; find weight of dilution by proportion. Answer is in Gm. Convert this to c.c.; then to f ℥. Ans. 24.17 f ℥.

10. A certain lump of opium on assaying is found to contain 9% of morphine, and 22% of moisture. What will be the morphine strength of the opium after drying [to make powdered opium]?

Solution.—If the opium contains 22 per cent. of moisture, 100 parts will make 78 parts of the dried opium. Since no morphine is lost in the drying, the percentage strength will be higher, i. e., the answer will be greater than 9 per cent. Hence—

78 parts : 100 parts :: 9% : (x) 11.53%

17. The official extract of nux vomica is a powdered extract, and is standardized to contain 15% of alkaloids. On evaporating the natural extract to dryness, it usually yields a product containing more than 15% of alkaloids. The diluent used is milk sugar; and to insure its thorough incorporation, it is to be added while the extract is still of the consistency of a syrup. To calculate at this point the amount of milk sugar required, it is necessary to know the alkaloidal strength of the syrupy extract, and also the percentage of moisture present.

Problem.—The syrupy extract of nux vomica is found to contain 14% of alkaloids, and 20% of moisture. How much milk sugar must be added to 600 Gm. of the extract in order to yield a product which after drying will contain 15% of alkaloids?

Solution.—(1.) If the moisture amounts to 20%, the yield of dry extract is 80% of 600 Gm.

100% : 80% :: 600 Gm. : (x) 420 Gm.
% of syr. ext. % of dry ext. wt. of syr. ext. wt. of dry ext.

(2.) The alkaloidal strength of the dry extract is greater than 14 per cent. Hence—

480 Gm. : 600 Gm. :: 14% : (x) 17.5%

(3.) If the strength of this dry extract is to be lowered from 17.5 per cent. to 15 per cent., the extract must be diluted to—

15% : 17.5% :: 480 Gm. : (x) 560 Gm.

(4.) To dilute the extract from 480 Gm. to 560 Gm., [560 Gm. — 480 Gm. =] 80 Gm. of milk sugar must be added.

The four steps of the process are:

(1). Finding the amount of dry extract the syrupy
extract will yield.

(2.) Finding the % strength of the dry extract.

(3.) Finding the weight to which the dry extract
would require dilution to reduce the
strength to 15%.

(4.) Finding by difference the amount of diluent to
be added.

18. A certain lot of syrupy extract of nux vomica contains 12% of alkaloids and 46% of moisture. How much milk sugar must be added to 5 lb. 6 oz. to yield a product containing 15% of alkaloids after drying? Ans. 22.35 oz.

19. A certain lump of opium contains 28 % of moisture, and 8% of morphine. (a.) How much morphine could be obtained from 500 Gm. of dried opium prepared from this lump? b.) How much milk sugar would be required to reduce 200 Gm. of the dried opium to a morphine strength of 10%? Ans. (a.) 55.55 Gm.; (b,) 22.22 Gm.

20. Tincture of ferric chloride has a sp. gr. of .96, and contains 13.6 % of anhydrous ferric chloride. The solution of ferric chloride has a sp. gr. of 1.387, and contains 37.8% of anhydrous ferric chloride. How many c.c. of the solution are required to make 100 c.c. of the tincture?

Solution.— 100 c.c. of tincture weigh 96 Gm.

Then—   37.8% : 13.6%   ::   96 Gm. : x
                      x = 34.54 Gm. = (Gm. of sol. required)
And 34.54 ÷ 1.387 (sp. gr.) = 24.9 +. Hence 34.54 Gm. = 24.9 c.c.

21. To make 100 c.c. of paregoric of the official strength, .4 Gm. of opium containing not less than 13% [nor more than 15%] of morphine, must be used. If the opium contains only 9% of morphine, how much should be used for each 100 c.c. of paregoric?

22. A Liter of a certain tincture is to contain 20 Gm. of drug, the standard alkaloid-strength of which is 1.5%. If the tincture were to be made from an extract (of the drug) of the alkaloid-content of 12%, how much of this extract should be used for each Liter of tincture?

CHAPTER VIII.

ALLIGATION.*

Alligation Medial.

COMPUTING THE PERCENTAGE STRENGTH OF A MIXTURE, OR
SOLUTION, WHEN THE AMOUNTS AND THE PERCENT-
AGE STRENGTHS OF THE SEVERAL INGREDIENTS
ARE GIVEN.

Problem.—A wholesale druggist mixes 5 lb. of opium
containing 9% of morphine, 3 lb. of opium containing 6%
of morphine, and 10 lb. of opium containing 12%. What
is the morphine strength of the mixture?

Solution.— 5 lb. of 9 per cent. opium contain as much morphine
as [5 × 9 =] 45 lb. of 1 per cent. opium would contain.

3 lb. of 6 per cent. opium contain as much morphine as [3 × 6
=] 18 lb. of 1 per cent. opium.

10 lb. of 12 per cent. opium contain as much morphine as [10 ×
12 =] 120 lb. of 1 per cent. opium.

Then the 18 lb. of product [5 lb. + 3 lb. + 10 lb.] contain as
much morphine as 183 lb. [45 lb. + 18 lb. + 120 lb.] of 1 per cent.
opium would contain. And the morphine strength of the product
must be as many times 1 per cent. as 18 lb. is contained in 183 lb.
183 ÷ 18 = 10.16. Hence the morphine strength of the product is
10.16 per cent.

This operation may be made the basis of the following
rule:

1. Multiply the amounts of the several ingredients (all
of which must be expressed in the same unit) by their per-
centage strengths.

*From the Latin *alligare*, to bind:—referring to the linking together of
values in alligation alternate, as shown on page 99.

$5[\text{lb.}] \times 9[\%] = 45. [\% \text{ units}].$
$3[\text{lb.}] \times 6[\%] = 18. [\% \text{ units}].$
$10[\text{lb.}] \times 12[\%] = 120. [\% \text{ units}].$

2.   Add the products.

$45 + 18 + 120 = 183 [\% \text{ units}].$

3.   Add also the amounts.

$5 + 3 + 10 = 18[\text{lb.}]$

4.   Divide the sum of the products by the sum of the amounts.

$183 \div 18 = 10.16.$

The quotient is the percentage strength of the mixture.

Note.—In case the strengths are given in volume-percentage, the amounts must be in volume; if in weight-percentage, the amounts must be in weight, as in the example.

Problems.

1.   A drug house receives two shipments of cinchona. The first, consisting of 500 lb., contains on an average 3.3% of quinine. The second, consisting of 300 lb., contains 2.1% of quinine. What is the quinine strength of the product obtained by mixing the two lots? Ans. 2.85%.

2.   A druggist finds in his laboratory the following lots of diluted alcohol: 1500 c.c., 60% by vol. strong, 400 c.c., 40% by vol. strong, 1 pint, 50% by vol. strong. What is the strength of the product obtained by mixing the three lots? Ans. 54.63%.

COMPUTING THE SPECIFIC GRAVITY OF A MIXTURE WHEN THE AMOUNTS AND THE SPECIFIC GRAVITIES OF THE INGREDIENTS ARE GIVEN.

The principles of alligation medial apply also to specific gravities. But it is required that the amounts be in volume,

and not in weight; for specific gravity expresses the weight of a unit of volume — not of a unit of weight.*

3. What would be the sp. gr. of the product obtained by mixing 3000 c. c. of benzin and 1200 c.c. of naphtha, the former having a sp. gr. of .67, and the latter of .718?

Solution.—

3000 c.c. $\times$ .67 [sp. gr.] = 2010 Gm.
1200 c.c. $\times$ .718 [sp. gr.] = 861.6 Gm.

4200 c.c.   2871.6 Gm.

2871.6 ÷ 4200 = .683 (sp. gr. of mixture).

4. What would be the sp. gr. of a mixture of 2 f ℥ of bromoform, sp. gr., 2.9, and 8 f ℥ of chloroform, sp. gr., 1.49? Ans. 1.77.

5. What would be the sp. gr. of a mixture of 150 Gm. of ether, sp. gr., .725, and 200 Gm. of chloroform, sp. gr., 1.49?

Suggestion.—Reduce Gm. to c.c.; then proceed by alligation medial. Ans. 1.026.

6. What would be the sp. gr. of a mixture of 1 pint of alcohol, sp. gr., .82, and 1 lb. of ether, sp. gr., .725? Ans. .7659.

---

*A cubic centimeter of water weighs 1 Gramme. A c.c. of a liquid having a sp. gr. of 3, weighs 3 Gm. On mixing 1 c.c. of water, sp. gr. 1, with 1 c.c. of the liquid, sp. gr., 3, we get 2 c.c. of product, weighing $1 + 3 = 4$ Gm. If 2 c.c. weigh 4 Gm., 1 c.c. will weigh 4 Gm. $\div 2 = 2$ Gm. Then the sp. gr. of the product must be 2, which by laboratory experiment can be proven to be correct.

But suppose that 1 Gm. of water and 1 Gm. of the liquid are mixed. What will be the sp. gr. of the product?

Misapplying the rule to weights we obtain the same answer as before—namely, sp. gr., 2. This cannot be correct if the answer to the first problem is correct; for the proportion of 1 Gm. of water to 1 Gm. of the liquid is the same as 1 c.c. of water to $\frac{1}{3}$ c.c. of the liquid, while in the first problem we have 1 c.c. of each. But on reducing the weights to volumes, and then applying the rule, we obtain for an answer the sp. gr. of 1.5.

1   c.c. $\times$ 1 [sp. gr.] = 1 Gm.
$\frac{1}{3}$ c.c. $\times$ 3 [sp. gr.] = 1 Gm.   Then $2 \div 1\frac{1}{3} = 1.5$. [sp. gr. of mixt.]

1 $\frac{1}{3}$ c.c.   2 Gm.

This by laboratory experiment can be proven to be correct. [In practice it is difficult to find two liquids of which one has a sp. gr. just three times that of the other. Even numbers were used in the example for sake of brevity and simplicity. For the laboratory experiment any two liquids which are miscible, and differ considerably in sp. gr., may be used.]

Alligation Alternate.

To Find the Proportion in Which Ingredients of Known Strength Must be Mixed to make a Mixture of Required Strength.

Problem.—In what proportion must opium 10% strong and opium 14% strong be mixed to make opium 13% strong?

Solution.—The strength of the stronger opium is 1% too high; that of the weaker opium is 3% too low. Since the difference between the strength of the stronger opium and the required strength is just $\frac{1}{3}$ as great as the difference between the strength of the weaker opium and the required strength, three parts of the stronger opium must be taken to one part of the weaker. In other words, the excess in strength of three parts of the stronger opium will just balance the deficiency of one part of the weaker opium.

Problem.—In what proportion must opium 10% strong and opium 15% strong be mixed to make opium 13% strong?

Solution.—The weaker opium is 3% too weak; the stronger is 2% too strong. Then the excess in strength of 3 parts of the stronger will just balance the deficiency of 2 parts of the weaker. For 2 [parts] $\times$ 3 [%] = 6; and 3 [parts] $\times$ 2 [%] = 6.

[The same principle applies in alligation alternate as is applied in writing chemical formulae.—The formula for zinc phosphide is $Zn_3 P_2$. Now zinc has 2 valencies, and phosphorus has 3. Hence 3 atoms of bivalent zinc have as many valencies (6) as 2 atoms of trivalent phosphorus. In like manner 3 parts of the opium which is 2% too strong will fortify to the required strength 2 parts of the opium which is 3% too weak.]

General Rule.

Per cent. of *stronger* ingredient minus desired per cent. equals parts of *weaker* ingredient.

Per cent. desired minus per cent. of *weaker* ingredient equals parts of *stronger* ingredient.

In case there are more than two ingredients, their percentage strengths must be paired off so that the difference between each percentage strength and the required percentage strength is just compensated for by the proper number of parts of the opposite kind.

Problem.—In what proportion must alcohol, 20% strong, alcohol, 40% strong, alcohol, 65% strong, and alcohol, 90% strong, be mixed to make alcohol which is 50% strong.

Proceed as follows:

1. Write the percentages in a column [preferably in numerical order]. Place a brace [{] in front of the column, and in front of the brace write the required percentage. Thus—

$$50\ \% \left\{ \begin{array}{l} 20\% \\ 40\% \\ 65\% \\ 90\% \end{array} \right.$$

2. Connect with a line each percentage which is greater than the required percentage with one that is less than the required percentage; and each one that is less with one that is greater than the required percentage. Thus—

$$50\% \left\{ \begin{array}{l} -20\% \\ \lceil 40\% \\ \lfloor 65\% \\ -90\% \end{array} \right. \quad \text{or} \quad 50\% \left\{ \begin{array}{l} -20\% \\ \lceil 40\% \\ \lfloor 65\% \\ 90\% \end{array} \right.$$

3. Write the difference between the first percentage and the required percentage opposite the percentage connected with the first percentage by a line. Proceed in this manner with all the percentages, in each case writing the difference not opposite the percentage compared, but opposite the percentage at the other end of the line. Thus—

$$50\% \left\{ \begin{array}{l} -20\% = 40 \\ \lceil 40\% = 15 \\ \lfloor 65\% = 10 \\ -90\% = 30 \end{array} \right.$$

The difference between 20% and 50% being 30%, 30 is placed opposite 90%.

The difference between 40% and 50% being 10%, 10 is placed opposite the 65%.

The difference between 65% and 50% being 15, 15 is placed opposite the 40%. The difference between 90% and 50% being 40, 40 is placed opposite the 20%.

The other answer is—

$$50\% \left\{ \begin{array}{l} \left[\begin{array}{l} -20 = 15 \\ \left[\begin{array}{l} 40 = 40 \\ 65 = 30 \\ 90 = 10 \end{array} \right. \end{array} \right. \end{array} \right.$$

The differences denote the number of parts which should be used of the several ingredients to make a mixture of the desired strength. In case of weight-percentage the proportionate parts are parts by weight; and in case of volume percentage they are parts by volume.

Proof.

By Alligation Medial.

40 [parts] × 20 [%] = 800 [% units]
15 [parts] × 40 [%] = 600 [% units]
10 [parts] × 65 [%] = 650 [% units]
30 [parts] × 90 [%] = 2700 [% units]
———   ————
95 [parts]   contain   4750 [% units]
Then— 4750 ÷ 95 = 50%.

Remarks.—When there are more than three ingredients, a number of correct answers are possible, because the percentages may be paired off in different ways. And even in case of but three ingredients—when but one answer is obtainable by alligation—the ingredients may be mixed in an indefinite number of proportions. So the answer obtained by alligation, in case of three ingredients, is not the only correct answer: it is *a* correct answer. And the answers obtained by alligation in case of four or more ingredients, are *not all,* but *only some,* of the correct answers.

In Case Either the Weaker or the Stronger Ingredients Exceed in Number.

Problem.—A wholesale druggist has five lots of opium-- 8%, 10%, 12%, 14% and 15% morphine strength respectively. In what proportion *may* these be mixed in order to make a product of 13% morphine strength?

Remember that in no case can a weaker % be connected with a weaker, or a stronger with a stronger.

Proceed as in the preceding example, except that one of the percentages must be connected with *two* others:

$$13\% \begin{cases} \quad 8\% = 2 \\ \quad 10\% = 1 \\ \quad 12\% = 1 \\ \quad 14\% = 1 + 3 = 4 \\ \quad 15\% = 5. \end{cases}$$

As the 14% is connected with *two* other percentages, the difference between 14% and the required percentage must be placed opposite *both* the percentages thus connected; i. e., opposite the 10%, and the 12%. And the difference between 10% and 13%, and the difference between the 12% and 13%, are both to be placed opposite the 14%.

Question.—How many correct answers to this problem are obtainable by alligation alternate?

Problems.

7. In what proportion should alcohol, 91% strong, be mixed with alcohol, 48% strong, to make alcohol 70% strong? Ans. 22 parts of 91% and 21 parts of 48%.

8. In what proportion must cinchona containing 11% of total alkaloid, cinchona containing 8%, and cinchona containing 4%, be mixed to make a product containing 5% of alkaloids? Ans. 1 part of 11%, 1 part of 8%, and 9 parts of 4%.

9. In what proportion should jalap containing 5% resin, jalap containing 7%, jalap containing 4%, and jalap

containing 3%, be mixed to make a product containing 6%?

In case of fractional parts.

10. In what proportion must coca .8% strong be mixed with coca .38% strong to make a product .5% strong?

Solution.—

.50 per cent. $\begin{cases} \text{.38 per cent.} = \text{.30 parts, which} \times 100 = 30 \text{ parts.} \\ \text{.80 per cent.} = \text{.12 parts, which} \times 100 = 12 \text{ parts.} \end{cases}$

Note.—As fractions are cumbersome, eliminate them by multiplication. In this case multiply by 100.

11. In what proportion should belladonna .38%, belladonna, .18%, and belladonna, .30%, be mixed to make a product .35% strong? Ans. 22 parts of .38%, 3 parts of each of the others.

In Case Active Constituents, or Diluents, or Both are Ingredients in the Mixture.

Problem.—In what proportion must chloroform be added to a 20% solution of chloroform to increase the strength of the latter to 35%?

Solution.—The chloroform figures in the calculation as a 100 per cent. solution, thus—

35 per cent. $\begin{cases} 20 \text{ per cent.} = 65 \text{ parts} \qquad = 13 \text{ parts.} \\ \qquad\qquad \text{or by cancellation} \\ 100 \text{ per cent.} = 15 \text{ parts} \qquad = 3 \text{ parts.} \end{cases}$

Then 65 parts of solution require 15 parts of chloroform. Or, reducing the ratio to its simplest expression by cancellation— 13 parts of solution require 3 parts of chloroform.

Problem —In what proportion should alcohol, 91% strong, alcohol, 48% strong, and water be mixed to make a product 35% strong?

Solution.—The water may be considered as an alcohol of zero percentage. Then—

$$35\% \begin{cases} \begin{array}{|l} \boxed{} \ 0\% \ (\text{water}) = 13 + 56 = 69 \text{ parts.} \\ \phantom{\boxed{x}} 48\% = 35 \text{ parts.} \end{array} \\ 91\% = 35 \text{ parts.} \end{cases}$$

Problems.

12. In what proportion must potassium iodide be added to a potassium iodide solution 15% strong in order to increase its strength to 25%? Ans. 2 parts of potass. iodide to 15 parts of 15% solution.

13. In what proportion should opium 10% strong, opium 15% strong, and milk sugar be mixed to make a product 13% strong? Ans. 2 parts of 10%, 16 parts of 15%, and 2 parts of milk sugar.

14. In what proportion should absolute acetic acid, acetic acid 36% strong, and water be mixed to make acetic acid 60% strong?

To Find the Proportion in Which Ingredients of Given Specific Gravities Must be Mixed to Make a Mixture of Given Specific Gravity.

Alligation alternate is applicable to volumes of liquids and their specific gravities.*

Problem.—In what proportion by volume must petrolatum, sp. gr., .82, be mixed with petrolatum, sp. gr., .85, to make a product having the sp. gr. of .83?

Solution.—

$$.83 \begin{cases} \begin{array}{|l} .85 = .01 \times 100 = 1. \text{ parts.} \\ .82 = .02 \times 100 = 2. \text{ parts.} \end{array} \end{cases}$$

Eliminating the fractions, the answer is, 2 parts by

---

*The parts calculated from specific gravities are in every case parts by volume. See page 97.

In some instances changes in volume take place, due to chemical action. The answers obtained are then only approximately correct. See dilution of alcohol, in U. S. P.

volume of the lighter to 1 part by volume of the heavier pa-trolatum.

Problems.

15. In what proportion by volume should ether, sp. gr., .725, chloroform, sp. gr., 1.49, and alcohol, sp. gr., .82, be mixed to make a product having the sp. gr. of 1.000? Ans. Ether, 49 p., chloroform, 45.5 p., alcohol, 49 p.

16. In what proportion by volume should glycerin, sp. gr., 1.25, alcohol, sp. gr., .82, be mixed to make a product having a sp. gr. of .95? Ans. Glycerin 13 p., alcohol, 30 p.

17. In stock we have two solutions of soda, the sp. gr. of one being 1.06, that of the other, 1.5. In what proportion must these be mixed to yield a product of the sp. gr. of 1.225? Ans. 5 p. of 1.06 sp. gr. to 3 p. of 1.5 sp. gr.

In Case the Quantity of One of the Ingredients is Specified, and the Quantity of the Other Ingredients is to be Calculated.

Problem.—How much scammony having a resin-content of 82% must be mixed with 5 lb. of scammony having a resin-content of 93%, to make a product having a resin-content of 90%?

Solution.—By alligation alternate we determine in what proportion the two qualities must be mixed:

90 per cent. $\begin{cases} 82 \text{ per cent.} = 3 \text{ parts.} \\ 93 \text{ per cent.} = 8 \text{ parts.} \end{cases}$

From the proportionate parts we calculate the quantities by proportion.

The three known terms are—3 parts, 8 parts, and 5 lb. Since quantity (weight) is asked for, 5 lb. must be the third term. The quantity of the weaker scammony is asked for; and as this is to be used in the proportion of 3 parts to 8 of the other, 3 being less than 8, the answer is to be smaller than 5 lb. Hence—

8 parts : 3 parts : : 5 lb. : (x) 1⅞ lb. = 1 lb. 14 oz.

In order that confusion may be avoided it is well to place the given quantity opposite the proportionate parts

which are to be taken of the ingredient for which the quantity is given, and to place an interrogation point to indicate the quantities sought; thus—

$$90 \ \% \ \left\{ \begin{array}{l} 82\% = 3 \text{ parts} = ? \\ 93\% = 8 \text{ parts} = 5 \text{ lb.} \end{array} \right.$$

The known terms may now be located without difficulty; and whether the answer should be greater or smaller than the given quantity—the third term—may be seen by inspection. The interrogation point follows "3 parts" in the example; a given quantity follows "8 parts." Since 3 is smaller than 8, the answer must be smaller than 5 lb.—the given quantity.

Problem—How much alcohol, 45% strong, how much 60% strong, and how much water, should be mixed with 500 Gm. of alcohol, 90% strong, in order that the product may have a strength of 50%?

Solution.—

$$50\% \ \left\{ \begin{array}{ll} 0\% \text{ (water)} = 40 \text{ parts} = ? \\ \left[\begin{array}{l} 45\% \\ 60\% \end{array} \right. = 10 \text{ parts} = ? \\ = 5 \text{ parts} = ? \\ 90\% = 50 \text{ parts} = 500 \text{ Gm} \end{array} \right.$$

Then by proportion*:

50 parts : 40 parts : : 500 Gm. : x (400 Gm.)
50 parts : 10 parts : : 500 Gm. : x (100 Gm.)
50 parts : 5 parts : : 500 Gm. : x (50 Gm.)

Proof.

400 Gm. $\times$ 0% = 0% unit
100 Gm. $\times$ 45% = 4500% units
50 Gm. $\times$ 60% = 3000% units
and 500 Gm. $\times$ 90% = 45000% units
_____ _____
1050 Gm. = 52500% units

52500 ÷ 1050 = 50 [%].

_____
* The general proportion is—
parts of ingredient, quantity **of** which is given : parts of ingredient,
quantity of which is sought : : quantity given : x
x = quantity sought.

Problems.

18. How many Gm. of nitric acid, 68% strong, must be added to 500 Gm. of acid, 10% strong, to make a product 50% strong? Ans. 1111.111 Gm.

19. How many Gm. of sulphuric acid, 90% strong, must be added to 1 L. of water to make an acid 10% strong?

20. How many c.c. of water should be added to 1 L. of a solution of soda, sp. gr., 1.4, in order to make a solution of the sp. gr. of 1.2?

21. How many f℥ of ammonia water, sp. gr., .96, must be added to 8 f℥ of ammonia water, sp. gr., .92, to make a product having a sp. gr. of .95? Ans. 24 f℥.

22. How many c.c. of ether, sp. gr., .725, must be added to 1 L. of chloroform, sp. gr., 1.49, to yield a product of the sp. gr. of 1.25? Ans. 457.14 c.c.

In Case the Quantity is Specified for Several Ingredients.

Problem.—We have 5 lb. of acetic acid, 28% strong, 3 lb. of acetic acid, 20% strong, and 1 lb., 10% strong. How much glacial acetic acid, 99% strong, should be added to a mixture of these in order that the product may have the strength of 36%?

Solution.—

$$
\begin{array}{llll}
5 \text{ lb.} & \times & 28 \% & = & 140 \% \text{ units} \\
3 \text{ lb.} & \times & 20 \% & = & 60 \% \text{ units.} \\
1 \text{ lb.} & \times & 10 \% & = & 10 \% \text{ units.} \\
\hline
9 \text{ lb.} & & & = & 210\% \text{ units} \\
& 210 & \div & 9 & = 23 \tfrac{1}{3} \%
\end{array}
$$

A mixture of the given quantities would be 23⅓% strong, and the weight of the mixtures would be 9 lb. The problem has now been simplified to — How much acetic acid 99% strong must be added to 9 lb. of acid 23⅓% strong, to make a product 36% strong?

$$36 \% \begin{cases} 23\frac{1}{3}\% = 63 & \text{parts} = 9 \text{ lb.} \\ 99 \ \% = 12\frac{2}{3} & \text{parts} = ? \end{cases}$$

Then— 63 parts : 12 $\frac{2}{3}$ parts :: 9 lb. : (x) 1 $\frac{56}{63}$ lb. = 1 lb. 12 oz. 417 gr.

Problems.

23. A druggist has 400 Gm. of opium, 10% strong, 350 Gm., 12% strong. How much opium, 16% strong, should he add to a mixture of the 10% and the 12% opium to make a product 13% strong? Ans. 516.66 Gm.

24. How much ammonia water, 28%, should be added to a mixture of 5 lb. of ammonia water, 10%, and 300 Gm., 8%, to make a product 15% strong.

25. In a laboratory there are three lots of solution of potassium iodide as follows:—400 Gm. of 5%, 200 Gm. of 12%, and 300 Gm. of 15%. How much potassium iodide must be dissolved in a mixture of the three lots to make a product 25% strong? Ans. 181.33 Gm.

In Case the Quantity of Product Wanted is Specified, and Quantity of Each of the Ingredients is to be Calculated.

Problem.—How much cinchona, quinine-strength, 3.9% and how much cinchona, 2.4%, must be used to make 10 lb. of a product having a quinine-strength of 3%?

$$Solution.—3\% \begin{cases} 2.4\% = .9 \times 10 = & 9 \text{ parts} = ? \\ 3.9\% = .6 \times 10 = & 6 \text{ parts} = ? \end{cases}$$

$$\overline{ 15 \text{ parts} = 10 \text{ lb.}}$$

If 6 parts and 9 parts are mixed, the product will be 15 parts. Then to make 15 parts of the product 9 parts of the cinchona, 2.4%, must be used; and from these 9 parts the quantity for 10 lb. may be found by proportion, weights being proportional to proportionate parts.

Thus— 15 parts : 9 parts : : 10 lb. : (x) 6 lb.*

In like manner the quantity of the stronger cinchona may be calculated:

15 parts : 6 parts :: 10 lb. : (x) 4 lb.*

Proof.

6 lb. $\times$ 2.4% $=$ 14.4% units.
4 lb. $\times$ 3.9% $=$ 15.6% units.
——— ————
10 lb.   30.0% units.
$$30 \div 10 = 3\%$$
and
6 lb. $+$ 4 lb. $=$ 10 lb.

Problems.

26. How many Gm. of colchicum, alkaloidal strength, .4%, and how many Gm. of the strength of .56%, must be used to make 20 Kgm. of product of an alkaloidal strength of .5%? Ans. 7500 Gm. of .4%, and 12500 Gm., of .56%.

27. How many gr. of mercuric chloride must be added to how many gr. of mercuric chloride solution, 2% strong, to make 500 gr. of a solution which is 5% strong?

28. 5 lb. of opium containing 14% of morphine is wanted. How much 9% opium, how much 11%, and how much 15.4% may be used to make a mixture of required weight and strength. Ans. of 9% and 11% each .648 + lb.; of 15.4 %, 3.7 + lb.

———

*—It will be observed that the general proportion is: Sum of the parts : parts of the ingredient : : weight of the mixture : x. x = weight of the ingredient.

Observe that the sum of the proportionate parts enters into the calculation only when the quantity of the entire mixture is used as a basis for the calculation of the amounts of the ingredients. When the amount of one ingredient is calculated from the amount of another ingredient, the sum is *not* used.

In Case Quantity of Product Wanted, and also the Quantity of One or More Ingredients is Specified.

Problem.— 1000 Gm. of alcohol, 50% strong, is to be made from 100 Gm. of 80% alcohol, by the addition of 40% and 65% alcohol. How much of each of the latter two strengths should be used?

Solution.—50% $\left\{ \begin{array}{l} 80\% = 10 \text{ parts} = 100 \text{ Gm.} \\ 40\% = 30 \text{ parts} = ? \end{array} \right.$

10 parts : 30 parts :: 100 Gm. : (x) = 300 Gm.

To reduce the 100 Gm. of 80% to the desired percentage 300 Gm. of 40% must be used. This will make 400 Gm. of mixture. But 1000 Gm. are wanted. 1000 Gm. — 400 Gm. = 600 Gm., which is the amount to be made by mixing 40% and 65% alcohol.

50% $\left\{ \begin{array}{l} 40\% = 15 \text{ parts} = ? \\ 65\% = 10 \text{ parts} = ? \end{array} \right.$

25 parts = 600 Gm.

25 parts : 15 parts :: 600 Gm. : (x) 360 Gm. of 40%
and 25 parts : 10 parts :: 600 Gm. : (x) 240 Gm. of 65%

Proof.

100 Gm. of 80% = 8000% units.
300 Gm. of 40% = 12000% units.
360 Gm. of 40% = 14400% units.
240 Gm. of 65% = 15600% units.

1000 Gm.   50000% units.

50000 ÷ 1000 = 50 [%].

CHAPTER IX.

CHEMICAL PROBLEMS.

Problems Based on Chemical Formulas.

Molecules.—It is a generally accepted theory that matter is not infinitely devisible, but that, when division has been carried to a certain extent, particles will be obtained which cannot be divided without destroying the chemical character of the substance. These particles have been called molecules. They are inconceivably small; but how small— of what volume, and of what weight—is not known*.

Atoms.—Nevertheless, molecules are—so it is generally believed—composed of still smaller particles, which are called atoms. An atom may be defined as the smallest particle of an element known to exist *in combination.*†

To show more clearly the relationship of atoms to molecules the following application of these definitions may be of service: The molecule of hydrochloric acid is a particle of that substance so small that it cannot be further divided into particles having the properties of hydrochloric acid. However, by chemical means, the particle can be divided into two dissimilar particles—hydrogen, and chlorin, each of which is different from the acid, the latter having been destroyed. The fact that such division is possible, indicates that molecules are composed of still smaller particles.

Atomic Weights.—Of the size and actual weight of atoms no more is known than of the size and weight of molecules.

However, the *relative weights* of atoms have been determined with considerable accuracy. To illustrate: the weight of an atom of sulphur is not known; but it is known

*According to calculations based upon the kinetic theory of gases, a molecule of hydrogen weighs about .000,000,000,000,000,000,000,004 Gm. But accuracy is not claimed for this result.

†When an element exists free, its smallest particle is a molecule. The molcules of most elements appear to contain two atoms; but mercury, zinc, and cadmium each contain but one atom in a molecule; while phosphorus, and arsenic each contain four.

that an atom of sulphur weighs about twice as much as an atom of oxygen, and 31.83 times as much as an atom of hydrogen—whatever weight that is.

It is to these relative weights that the term *atomic weights* is applied.

The atomic weights as usually given are referable to the weight of a hydrogen atom, this being expressed by unity— by 1.000. The weight of a hydrogen atom was selected as the standard because the atom of hydrogen weighs less than the atom of any other element.

Accordingly the atomic weight of oxygen is 15.88, which means that an atom of oxygen weighs 15.88 times as much as an atom of hydrogen. The atomic weight of nitrogen is 13.93; that of sulphur is 31.83, etc.—A table of atomic weights is given on the last page.

[By some authorities the atom of oxygen with the weight of 16 [O = 16], is taken as the standard. The chief advantages claimed for the oxygen standard are: (1.) the atomic weights of a larger number of the elements are whole numbers; (2.) in atomic weight determinations it is impossible in case of most elements to make a direct comparison with hydrogen, while direct comparison with oxygen presents no special difficulties.]

Molecular Weights.—Molecular weight, like atomic weight is *relative*—not actual—weight. The standard for atomic weights is the standard for molecular weights as well. It follows then that the molecular weight of a compound is the weight of its molecule as compared with the weight of an *atom* of hydrogen;—that is, if the standard of H = 1.000 is employed. It follows also that the molecular weight will, in every instance, be equal to the sum of the weights of the atoms in the molecule. Hence, in case of elements, the atomic weight may be calculated from the molecular weight; for mol. wt. ÷ no. of atoms in molecule = at.wt. And, on the other hand, if the molecular formula of a compound is known, and also the atomic weight of each of the elements in the compound, the molecular weight may be obtained by calculation.

CALCULATION OF MOLECULAR FORMULA.

The following data are necessary, and are, of course, determined experimentally:

1. The molecular weight of the compound.

2. The identity of the elements in the compound, and the atomic weights of these elements.

3. The proportion in which the component elements are present. [Expressed in parts by weight, usually in percentage.]

Problem.—Suppose the molecular weight of the compound has been found to be 90; and the percentage composition as follows:—carbon, 40%, hydrogen, 6⅔%, oxygen, 53⅓%. Assuming the atomic weight of hydrogen to be 1, carbon 12, and oxygen 16, what is the formula of the compound?

Process.—First calculate how many parts of each of the three elements would be present in 90 parts, 90 being the molecular weight:

100% : 40 % :: 90 parts : x (36 parts).
100% : 6⅔ % :: 90 parts : x (6 parts).
100% : 53⅓% :: 90 parts : x (48 parts).

Then divide the parts for each of the elements by the atomic weight of that element. Thus—

Carbon, 36 parts ÷ 12 (at. wt.) = 3.
Hydrogen, 6 parts ÷ 1 (at. wt.) = 6.
Oxygen, 48 parts ÷ 16 (at. wt.) = 3.
The molecular formula is $C_3H_6O_3$.

Note.—The calculation is here simplified by use of approximate atomic weights. In practice the accurate atomic weights are employed.

CALCULATION OF MOLECULAR WEIGHT FROM MOLECULAR FORMULA.

As has been stated, the molecular weight of a compound must be determined experimentally before it becomes possible to deduce the molecular formula. But when the latter

is known, the molecular weight may be calculated *from* the formula; for *the molecular weight is the sum of the weights of the atoms in the molecule.*

For instance:—The molecular weight of NaI is the atomic weight of Na = 22.88, plus the atomic weight of I = 125.89; hence is 148.77. The molecular weight of O_3 [Ozone] is the atomic weight of O = 15.88 taken 3 times; hence is, 47.64. The molecular weight of HNO_3 is the atomic weight of H = 1, plus the atomic weight of N = 13.93, plus 3 times the atomic weight of O = 15.88, which is 47.64; hence the molecular weight of HNO_3 is 1 + 13.93 + 47.64 = 62.57.

Problem.—Calculate the molecular weight of H_2SO_4.
Solution :—

$$
\begin{aligned}
H_2 &= 1 \times 2 = 2 \\
S &= 31.83 \times 1 = 31.83 \\
O_4 &= 15.88 \times 4 = 63.52
\end{aligned}
$$

Mol. wt. of $H_2SO_4 = 97.35$
Note.—The numbers in italics are the atomic weights.

Problem.—
Calculate the molecular weight of $Na_2CO_3.10H_2O$.
Solution.—

$$
\begin{aligned}
Na_2 &= 22.88 \times 2 &&= 45.76 \\
C &= 11.91 \times 1 &&= 11.91 \\
O_3 &= 15.88 \times 3 &&= 47.64 \\
10\ H_2 &= 1 \times 10 \times 2 &&= 20 \\
10\ O &= 15.88 \times 10 &&= 158.8
\end{aligned}
$$

Mol. wt. of $Na_2CO_3.10H_2O = 284.11$

Problem.—Calculate the molecular weight of $(MgCO_3)_4.Mg(OH)_2.5H_2O$.

Solution.—Reducing the rational formula to an empirical formula we have $Mg_5C_4O_{19}H_{12}$.

And—
$$
\begin{aligned}
Mg_5 &= 24.18 \times 5 = 120.94 \\
C_4 &= 11.91 \times 4 = 47.64 \\
O_{19} &= 15.88 \times 19 = 301.72 \\
H_{12} &= 1 \times 12 = 12
\end{aligned}
$$

Mol.wt. of $(MgCO_3)_4.Mg(OH)_2.5H_2O = 482.3$

Problems.

These answers were obtained by use of accurate atomic weights. The student may, however, shorten the work of figuring by using approximate atomic weights in all cases when the calculations are performed merely for practice, and not in connection with laboratory exercises.

1. Calculate the molecular weight for (a.) H_2O; (b.) $NaOH$; (c.) $HgCl_2$; (d.) $C_{10}H_8$. Ans. (d.) 127.1.

2. For—(a.) $FeSO_4.7H_2O$; (b.) $Fe_2(PH_2O_2)_6$; (c.) $HC_3H_5O_3$. (d.) $Al_2K_2(SO_4)_4.24H_2O$. Ans. (d.) 942.

3. For—(a.)$C_{12}H_{22}O_{11}$;(b.)$CHCl_3$. Ans. (a.)339.6.

4. For—$C_{20}H_{24}N_2O_2.3H_2O$ (Quinine). Ans. 375.46.

5. For—$(C_{21}H_{22}N_2O_2)_2 H_2SO_4 .5H_2O$ (Strychnine Sulphate). Ans. 850.21.

Note.—Remember that a subscript following a symbol applies to that symbol only; that a subscript following parentheses multiplies all within the parentheses; and that a coefficient preceding a formula multiplies the entire formula. If, however, the coefficient precedes only part of a formula, only the portion which follows is affected by the coefficient. Thus in the formula $K_4Fe(CN)_6 3H_2O$ the subscript 4 multiplies K; the subscript 6 multiplies C and N; and the coefficient 3 multiplies H_2O.

Calculation of the Percentage Composition of a Compound from its Formula.

Problem.—Calculate the percentage composition of Fe_2O_3.

Solution.— $Fe_2 = 55.5 \times 2 = 111$
            $O_3 = 15.88 \times 3 = 47.64$
                                     _____

            Mol. wt. of $Fe_2O_3 = 158.64$

Atomic weights, and hence also molecular weights, may be considered as *parts by weight*. It follows then that 158.64 parts of Fe_2O_3 contain 111 parts of Fe. From these data the percentage of Fe may be calculated by proportion in the usual manner:

The three known terms are, 158.64 parts, 111 parts, and 100%. The answer is to express %. Hence—

            :   ::   100%   :   ::

The answer is to be smaller than 100%, because a part must be smaller than the whole. Hence—

158.64 parts : 111 parts :: 100% : x
$$x = 69.96\% = \% \text{ of Fe.}$$

In like manner the percentage of O may be calculated:

158.64 parts : 47.64 parts :: 100% : x
$$x = 30.04 \% = \% \text{ of O.}$$

Problem.—What is the percentage composition of $C_6H_{12}O_6$?

Solution.—

$$\begin{aligned}
C_6 &= 11.91 \times 6 = 71.46 \\
H_{12} &= 1 \times 12 = 12 \\
O_6 &= 15.88 \times 6 = 95.28
\end{aligned}$$

$$178.74$$

Then—

178.74 parts : 71.46 parts :: 100% : x
$$x = 39.979\% = \% \text{ of C.}$$

178.74 parts : 12 parts :: 100% : x
$$x = 6.713\% = \% \text{ of H.}$$

178.74 parts : 95.28 parts :: 100% : x
$$x = 53.306\% = \% \text{ of O.}$$

Problems.

6. Calculate the percentage composition of—(a.) H_2O; (b.) H_2O_2; (c.) H_3PO_4; (d.) $C_{12}H_{22}O_{11}$; (e) $C_{20}H_{24}N_2O_2.3H_2O$ [quinine]. Ans. (a.) 11.18 + % of H and 88.81 + % of O.

THE PERCENTAGE-CONTENT OF ONLY ONE ELEMENT OR GROUP OF ELEMENTS IS REQUIRED.

Problem.—What is the percentage of iron in $FeSO_4.7H_2O$?

Solution.—

$$\begin{aligned}
Fe &= 55.5 \times 1 &= 55.5 \\
S &= 31.83 \times 1 &= 31.83 \\
O_4 &= 15.88 \times 4 &= 63.52 \\
7H_2 &= 1 \times 7 \times 2 &= 14 \\
7O &= 15.88 \times 7 &= 111.16
\end{aligned}$$

Mol. Wt. of $FeSO_4. 7H_2O = 276.01$

Then—   276.01 parts : 55.5   ::   100%   :   x
                x $= 21\% = \%$ of Fe.

Problem.—Calculate the percentage of water of crystallization in $Na_2CO_3.10H_2O$.

Solution.—The molecular weight of $Na_2CO_3.10H_2O$ is 284.11.

The molecular weight of H_2O is 17.88; hence the relative weight for the ten molecules is 178.8.

In other words, 284.11 parts of $Na_2CO_3.10H_2O$ contain 178.8 parts of water.

Then—284.11 parts : 178.8 parts : : 100% : x (62.9%)

Problems.

7.   What % of anhydrous $FeCl_3$ in $FeCl_3.6H_2O$?
8.   What % of Fe in $FeCl_3.6H_2O$? Ans. 20.69%.
9.   What % of C in CH_4?
10.   What % of I in CHI_3 [iodoform]. Ans. 96.6+%.
11.   What% of I in C_4NHI_4 [iodol]. Ans. 89%.
12.   What % of arsenic in realgar—an arsenical ore of the composition As_2S_2?
13.   What % of zinc in sphalerite—a zinc ore of the composition of ZnS? Ans. 67%.
14.   What %of water of crystallization in $FeSO_4.7H_2O$?
15.   In making dried sodium carbonate the crystallized sodium carbonate is heated until it has lost one-half its weight. What % of water of crystallization remains in the dried carbonate?

Solution.—Mol. wt. of $Na_2CO_3.10H_2O = 284.11$.

If the weight is reduced to one-half, the molecular weight of the product must be $284.11 \div 2 = 142.055$. The molecular weight of anhydrous $Na_2CO_3 = 105.31$. Then 142.055 minus $105.31 = 36.745 =$ weight of water in the molecule of dried carbonate.

And 142.055 parts   :   36.745 parts :: 100% : x(25.86%)

16.   How many molecules of water of crystallization in the dried sodium carbonate (U. S. P.)?

Solution.—If the molecular weight is one-half that of the crystallized carbonate, there are about 36.745 parts of water present; for $142.055 - 105.31 = 36.745$. And

36.745 ÷ 17.88 (mol. wt. of H_2O) = 2 +. So a little over two molecules are present; and the formula $Na_2CO_3.2H_2O$ is nearly correct for the official dried carbonate.

Calculations Based on Chemical Reactions.

Atomic weights are relative weights, and for arithmetical purposes may be thought of as parts by weight. This being true of atomic weights, it must be true also for molecular weights and for multiples of molecular weights.

By the equation—

$Zn + H_2SO_4 = ZnSO_4 + H_2$ it is indicated that an atom of zinc requires a molecule of absolute sulphuric acid in order to make a molecule of zinc sulphate, and two atoms [a molecule] of hydrogen.* Now if the atomic weight of Zn is 64.9, and the molecular weight of H_2SO_4 is 97.35, it follows that 64.9 parts by weight of Zn will require 97.35 parts by weight of H_2SO_4. And if the molecular weight of $ZnSO_4$ is 160.25, and the atomic weight of H is 1, 160.25 parts by weight of $ZnSO_4$ and 2 parts by weight of H will be the products of the reaction. Thus—
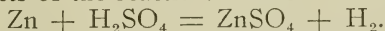
$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$
$$64.9 + \quad 97.35 \quad = 160.25 + 2.$$

Problem.—How many Gm. of abs. H_2SO_4 is required to convert 50 Gm. of Zn into Zn SO_4?

Solution.—Since atomic and molecular weights may be considered as indicating parts by weight, the problem may be stated as follows:—if 64.9 parts of Zn require 97.35 parts of H_2SO_4, 50 Gm. of Zn will require how many Gm. of H_2SO_4? The parts, being parts by weight, are proportional to Gm., and the answer may be found by proportion in the usual manner, as follows:

The answer is to express weight [Gm.]; hence the known term expressing weight must be the third.

: :: 50 Gm. : x

---

*In order that the reaction may occur as shown in the equation it is necessary that the acid used be diluted with considerable water, concentrated acid giving rise to other products, including SO_2 and H_2S. However, the water, though necessary, is the same on the product-side of the equation as on the factor-side, and hence does not enter into the calculations.

The answer is to be larger than 50 Gm., because the answer is to give the amount of H_2SO_4, and as it requires 97.35 parts of acid for 64.9 parts of Zn; i. e., it requires *more* acid than Zn., the answer will be larger than 50 Gm.

Hence—

64.9 parts : 97.35 parts   ::   50 Gm. : x (75 Gm.)

Problem.—How many Gm. of Zn will 75 Gm. of absolute H_2SO_4 convert into Zn SO_4?

Solution.—Weight is asked for; hence the known term expressing weight must be the third. The answer is to be smaller than 75 Gm., because is requires less Zn than H_2SO_4. Hence—

97.35 parts : 64.9 parts : : 75 Gm. : x (50 Gm).

In like manner—by proportion—the amount of $ZnSO_4$ formed may be calculated, as may also the amount of $\overline{H}$ evolved. Again, the amount of one of the products might be given. From it the amount of the other products may be calculated; also the amount of Zn, and the amount of H_2SO_4 required. In short, *if the quantity for any one member of an equation is given, the quantity for any other member may be found by proportion.*

It will be seen by close inspection that twelve distinct problems may be based on the equation given; and in case of equations of more than four members, the number of possible problems is correspondingly larger. Yet any and all may be solved by proportion, no specific rules being necessary. However, in order that there may be no mistake in selecting the terms for the proportion, the following procedure is recommended:

1.   Write the equation for the reaction on which the problem is to be based.

2.   Select the two members of the equation which figure in the problem; namely, (1.) the compound [or element] the quantity of which is *given* in the problem, and (2.) the compound [or element] the quantity of which is *sought*. Draw a line under each of the members of the equation thus selected; also indicate for which one the quantity is given and for which one it is sought.

3.   Calculate the reacting weight for each of these two

members of the equation, writing the reacting weight under the lines.

The term reacting weight is here used to indicate the atomic weight, molecular weight, or multiple of these, as required by the equation. If, in the latter, the molecule is multiplied by a coefficient, the molecular weight must be multiplied by the same coefficient, and the product used in the proportion.

4. Select the third term. When quantity is asked for, the quantity given in the problem must constitute the third term. However, since the other values are weights—reacting weights, considered as parts by weight—the quantities must be in weight; for volumes are not proportional to parts by weight.

5. Select the second term. Reacting weights [parts by weight] are *directly* proportional. Hence the answer will be larger than the third term if the reacting weight of the substance, the quantity of which is sought, exceeds the reacting weight of the substance, the quantity of which is given. Or, in other words, the reacting weight of the substance, the quantity of which is sought, must be the second term.

6. Then the reacting weight of the substance, the quantity of which is given, must be the first term, and the general proportion will be as follows:

Reacting weight of substance whose quantity is given *is to* the reacting weight of the substance whose quantity is sought *as* the quantity given *is to* the quantity sought. This must be so because the two values are *directly* proportional.

Application of Rule.

Problem.—How many Gm. of Zn are required to generate 30 Gm. of H?

Solution.—

1. Equation: $Zn + H_2SO_4 = H_2 + ZnSO_4$
2. Members required: $Zn + H_2SO_4 = H_2 + ZnSO_4$
                         sought   ·   *given*

9

3. Reacting weights $Zn + H_2SO_4 = H_2 + ZnSO_4$
    required: *sought*   *given*
                  64.9   2
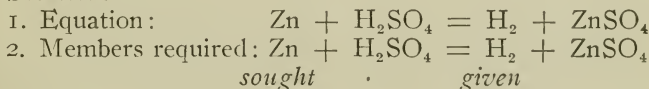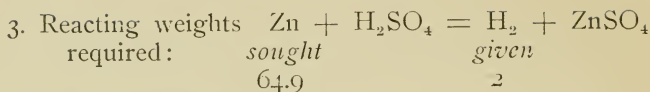
4. Third term selected:
    :   : :   30 Gm.   :   x.

5. To generate 2 parts of H requires *more* than 2 parts of Zn; therefore the answer must be larger than the third term.

Then—
    2 parts : 64.9 parts : : 30 Gm. : x (973.5 Gm.)

That is—
    React. wt. H. : React. wt.Zn : :   wt. H : wt. Zn.

It will be seen that the H and Zn alternate. This alternation of substances in the proportion—made necessary by the fact that the two values are *directly* proportional— may serve as proof that the first and second terms have been correctly placed.

Problem.—How many Gm. of ferric sulphate are required to make 100 Gm. of ferric hydroxide?

Solution.—Equation:
$$Fe_2(SO_4)_3 + 6NH_4OH = 2Fe(OH)_3 + 3(NH_4)_2SO_4.$$
    sought   *given*
    397.05   212.28
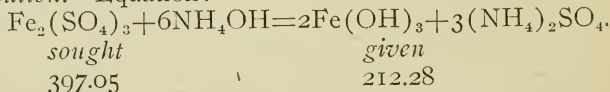
Then 212.28 parts : 397.05 parts : : 100 Gm. : x (187 Gm.)
    R. wt. $Fe(OH)_3$: R. wt. $Fe_2(SO_4)_3$: : Wt. $Fe(OH)_3$: Wt. $Fe_2(SO_4)_3$

Notice that the reacting weight of $Fe(OH)_3$ is twice its molecular weight [$106.14 \times 2 = 212.28$]; the equation showing that one molecule of $Fe_2(SO_4)_3$ will make two molecules of $Fe(OH)_3$.

Note.—On comparing the amounts given in the working formulas of text-books with the amounts of the factors as calculated from equations, great discrepancies will often be noticed. Thus, the amount of iron used in making FeI_2 is greatly in excess of the amount required by the equation. In like manner, ammonia water, when used to precipitate ferric salts, is used in considerable excess. Practical experience has proven such excess necessary.

[For explanations the student is referred to the standard works on theoretical chemistry, especially to the chapters on mass action, on the ion theory, and on chemical equilibrium.] However, even in these instances the quantities as calculated from the equation, form a basis for the working formula.

Problems.

Some of the answers which follow were obtained with approximate atomic weights.

17.   How much lime (CaO) can be made from 100 Gm. of marble ($CaCO_3$)?

Equation: $CaCO_3 + heat = CaO + CO_2$.

18.   How much carbon dioxide (CO_2) is formed at the same time?

19.   How much absolute H_2SO_4 is required to neutralize 50 Gm. of absolute NaOH?

Equation: $2 NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$.

20.   How much Na_2SO_4 is formed?

21.   How much water is formed as a by-product?

22.   How much Ca $(PH_2O_2)_2$ is required to make 2 oz. of KPH_2O_2? Ans. ~~68.375~~ gr. 7/5

Equation: $Ca(PH_2O_2)_2 + K_2CO_3 = 2KPH_2O_2 + CaCO_3$

23.   How much $CaCO_3$ is formed as a by-product?

24.   How many Gm. of silver nitrate can be made from 100 Gm. of silver?* Ans. 157.477 Gm.

Equation: $3 Ag + 4HNO_3 = 3 AgNO_3 + NO + 2 H_2O$.

25.   How much NO will be evolved? Ans. 9.2 Gm.

26.   How much absolute HNO_3 will be used for the purpose? Ans. 77.85 Gm.

27.   How much dried alum can be made from 50 Gm. of crystallized alum?

Note.—The dried alum is alum minus the water of crystallization: $Al_2K_2(SO_4)_4 .24H_2O = Al_2K_2(SO_4)_4 + 24 H_2O$.

28.   Hydriodic acid may be made by the interaction of potassium iodide and tartaric acid, as follows:

$I + H_2C_4H_4O_6 = HI + KHC_4H_4O_6$.

How much potassium iodide, and how much of tartaric acid, is required to make 50 Gm. of the hydriodic acid?

*In balancing oxidation and reduction equations employ Johnson's rule.

29. One pound of baking powder is to contain 9 oz. of cream of tartar, and enough baking soda for neutralization.* How much of the latter is required? Ans. 4.02 oz.

Equation:

$KHC_4H_4O_6 + NaHCO_3 = KNaC_4H_4O_6 + CO_2 + H_2O.$
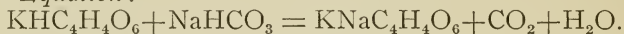
30. How much carbon dioxide would a pound of this baking powder yield? Ans. 2.1 oz.

31. A druggist has use for 200 gr. of lithium citrate. He has none in stock, but has the carbonate. So he decides to make the citrate from the carbonate by saturation with citric acid. How much of the carbonate should he use? Ans. 105.7 gr.

Equation:

$3Li_2CO_3 + 2H_3C_6H_5O_7 = 2Li_3C_6H_5O_7 + 3CO_2 + 3H_2O.$
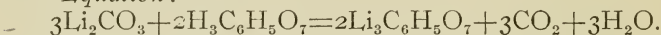
32. Mercuric oleate is made from 200 Gm. of mercuric oxide, and 800 Gm. of oleic acid. How much oleic acid is required to make the salt—mercuric oleate—and how much of the acid is present in the finished product as a diluent or vehicle? Ans. 522.3 Gm. combined and 277.6 + Gm. free.

Equation: $HgO + 2HC_{18}H_{33}O_2 = Hg(C_{18}H_{33}O_2)_2 + H_2O.$
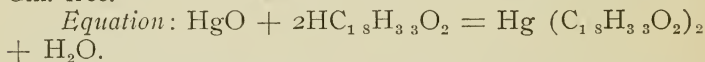
33. A druggist desires to make quinine bisulphate from the normal sulphate. How much absolute H_2SO_4 would be required by 100 Gm. of the normal salt? Ans. 11.256 Gm.

Equation: $(C_{20}H_{24}N_2O_2)_2H_2SO_4.7H_2O + H_2SO_4 + 7H_2O = 2C_{20}H_{24}N_2O_2H_2SO_4.7H_2O.$
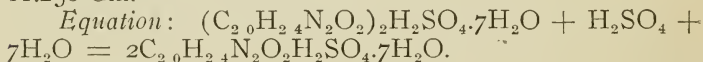
*The rest is corn starch.

CALCULATIONS BASED ON REACTIONS, BUT INVOLVING ALSO PERCENTAGE SOLUTIONS.

From the equation, $3Hg + 8HNO_3 = 3Hg(NO_3)_2 + 2NO + 4H_2O$, the amount of *absolute* HNO_3 required to dissolve a given amount of Hg can be calculated by proportion. However, the acid which is actually used in the operation is not absolute HNO_3, but is an aqueous solution

of the latter, 68% strong. A second calculation, in which it is determined how much 68% acid would be equivalent to [that is, would contain] the amount of absolute HNO_3 found by proportion, is therefore necessary, if the answer is to form the basis for practical work.

34. How many Gm. of nitric acid, 68% strong, are required to dissolve 20 Gm. of mercury as mercuric nitrate?

$$3Hg + 8HNO_3 = 3Hg(NO_3)_2 + 2NO + 4H_2O.$$
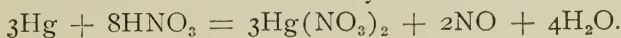
given   *sought*

595.5   500.56

595.5 parts : 500.56 parts   : :   20 Gm. : x (16.825 Gm.)

The answer indicates the amount of *absolute* HNO_3; and from this answer the amount of 68% acid containing 16.825 Gm. of absolute HNO_3, may be found by a second proportion. See chapter VI.

For this second proportion the three known terms are: 68%, 100% [the % of the abs. HNO_3], and 16.825 Gm. The answer is to express weight. Hence—

:   : :   16.825 Gm. : x

The answer is to be *larger* than 16.825 Gm., because the question is, how much of a weaker acid is equivalent to 16.825 Gm. of absolute HNO_3. Hence—

68% : 100% : : 16.825 Gm. : x (24.74 Gm.)

Accordingly, 24.74 Gm. of official nitric acid is required to dissolve 20 Gm. of mercury.

Note.—As has been stated before, dividing the divisor is equivalent to multiplying the dividend. It follows then that (16.825 Gm. × 100) ÷ 68 = 16.825 Gm. ÷ (68 ÷ 100). In other words, the amount of weaker acid may be found by dividing the amount of absolute acid by the percentage strength of the weaker acid, expressed in hundredths. Thus—

16.825 Gm. ÷ .68 = 24.74 Gm.

35. How many lb. of potassium acetate can be made from 50 lb. of acetic acid, 36% strong?

Remarks.—This problem may be solved in two ways: either the absolute acid in 50 lb. of the 36% acid may be

calculated, and this amount of absolute acid placed as the third term, in which case the fourth term will be the answer desired; or, the 50 lb. [of 36% acid] may be used as the third term, giving as the fourth term the amount of a 36% solution of potassium acetate, from which, by a subsequent calculation, the amount of [absolute] potassium acetate may be found.

Solution, the first-mentioned process being used.—

100% : 36% :: 50 lb. : x (18 lb.),

showing that the 50 lb. of 36% acid contain 18 lb. of absolute acid.

The problem has thus been simplified to—How much $KC_2H_3O_2$ can be made from 18 lb. of $HC_2H_3O_2$?

Equation:

$$HC_2H_3O_2 + KHCO_3 = KC_2H_3O_2 + CO_2 + H_2O.$$
   given   *sought*
   59.56   97.38
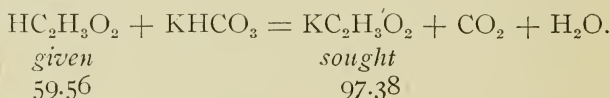
Then— 59.56 parts : 97.38 parts : : 18 lb. : x
x = 29.4 lb. = wt. of $KC_2H_3O_2$.

36. How many Gm. of $Na_2CO_3.10H_2O$ must be used to make 500 Gm. of 5% solution of NaOH?

Solution.— 100% : 5% : : 500 Gm. : x (25 Gm.), showing that the 500 Gm. of solution contain 25 Gm. of NaOH.

Equation:

$$Na_2CO_3.10H_2O + Ca(OH)_2 = 2NaOH + CaCO_3 + 10H_2O$$
   sought   *given*
   284.1   79.52
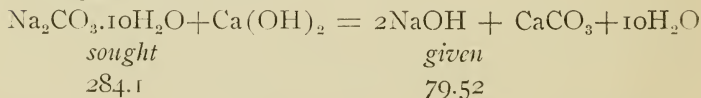
79.52 parts : 284.1 parts : : 25 Gm. :x (89.3 Gm.)

37. A druggist desires to prepare 250 Gm. of dil. HBr (10%) by the tartaric acid method. How much KBr and how much $H_2C_4H_4O_6$ are required? Ans. 36.73 Gm. of KBr and 46.33 Gm. of the acid.

Equation: $KBr + H_2C_4H_4O_6 = HBr + KHC_4H_4O_6$.

38.   HCN may be made extemporaneously from AgCN and HCl. How much hydrochloric acid, 31.9% strong, would be required by 1 oz. of silver cyanide?

Equation: $AgCN + HCl = AgCl + HCN$.

39.   How many gr. of dil. HCN (2% strong) would be produced?

40.   How much stearic acid, and how much crystallized sodium carbonate are required to make 500 Gm. of glycerin suppository mass, the latter to contain 4% of sodium stearate as stiffening agent?

Solution: 4 % of 500 = 20 Gm. (amt. of sod. stearate required).

Equation:

$$2\ HC_{18}H_{35}O_2 + Na_2CO_3.10H_2O = 2NaC_{18}H_{35} + CO_2 + 11H_2O$$

sought	given
564.28	608.04

Then— 608.04   :   564.28   : :   20 Gm. :   x
<small>R. wt. sod. stear.   :   R. wt. st. ac. : :   wt. sod. st. : wt. st. ac.</small>

And in like manner the amt. of sodium carbonate is found.

React. wt. sod. stear : react wt. sod. carb.   : :   20 Gm.   :   x.

41.   How much $HgCl_2$ is required to yield enough yellow mercuric oxide for ½ lb of stock ointment 40% strong?*

Equation: $HgCl_2 + 2NaOH = HgO + 2NaCl + H_2O$.

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*If the right amount of the oxide is precipitated, it is but necessary to wash, drain, and mix with enough wool fat to make ½ lb. of stock ointment, which may be quickly diluted as needed, yielding an ointment far superior to that made from the dried oxide by trituration.

PROBLEMS INVOLVING ALSO REDUCTION OF VOLUME TO
WEIGHT AND VICE VERSA.

42. How many grains of Zn would be converted into
$ZnCl_2$ by 200 c.c. of hydrochloric acid, sp. gr., 1.16, strength,
30%?

Solution.—   200 c.c. [$\times$ 1.16] = 232 Gm.

100% : 30% : : 232 Gm. : x (69.6 Gm. of abs. HCl).

Equation:— $Zn + 2HCl = ZnCl_2 + H_2.$
                 sought   given
                  64.9   72.36

Then—

72.36 parts : 64.9 parts : : 69.6 Gm. : x (62.4 Gm. of Zn.)

43. How many gr. of Li_2CO_3 would be dissolved as
LiCl by 1 f℥ of hydrochloric acid, sp. gr., 1.163, strength,
31.9%? Ans. 173.5 gr.

Equation: $Li_2CO_3 + 2HCl = 2LiCl + CO_2 + H_2O.$

44. How many c.c. of nitric acid, sp. gr., 1.414,
strength, 68%, can be made from 600 Gm. of $NaNO_3$? Ans.
462.5 c.c.

Equation:— $NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3.$

45. How many c.c. of sulphuric acid, sp. gr., 1.835,
strength, 92.5%, would be required by the 600 Gm. of
$NaNO_3$?

46. How many f℥ of ammonia water, sp. gr., .9
strength, 28%, could be neutralized with 500 c.c. of acetic
acid, sp. gr., 1.048, strength, 36%?

Solution.—

Step I: Finding amount of *absolute* acetic acid.

500 $\times$ 1.048 (sp. gr.) = 524 Gm. (wt. of acid).

Then 100% : 36% : : 524 Gm. : x (188.64 Gm. of ab-
solute acetic acid.)

Step II: Finding amount of abs. ammonia (NH_3)
this amount of abs. acid would neutralize.
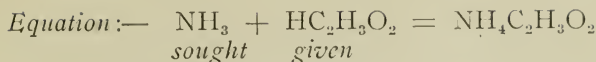
Equation:— $NH_3 + HC_2H_3O_2 = NH_4C_2H_3O_2$
           sought   *given*
           16.93   59.58
    59.58   :   16.93   : :   188.6 Gm.   :   x

$x = 53.6$ Gm. (am't of NH_3 neut. by 188.64 Gm. of abs. acid)

   Step III: Finding Gm. of 28% ammonia water equal to 53.6 Gm. of abs. NH_3.

      28% : 100% : : 53.6 Gm. : x (191.4 Gm.)

   Step IV: Reducing weight in Gm. to volume in f℥.

   191.4 ÷ .9 (sp. gr.) = 212.6 c.c.
and 212.6 c.c. ÷ 29.57 = 7.19 f℥.   (Ans.)

————o————

   Problems based on equations occur not only in manufacturing, but also in analytical chemistry.

   For instance:

   47.   1.2 Gm. of crude barium hydroxide is dissolved by aid of HCl; the resulting $BaCl_2$ precipitated as a sulphate—as $BaSO_4$, and the latter washed, dried and weighed. Its weight is found to be 1.6 Gm. What % of $Ba(OH)_2$ in the sample?

Equation: $Ba(OH)_2 + 2HCl = BaCl_2 + 2H_2O$
             $BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl.$
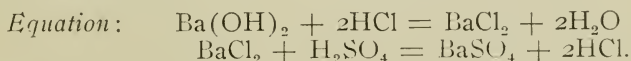
Solution: It will be seen that a molecule of $BaSO_4$ requires for its production a molecule of $Ba(OH)_2$. Hence 231.75 parts (mol. wt. of $BaSO_4$) of the precipitate indicate 170.16 parts (mol. wt. of $Ba(OH)_2$). And since all the $Ba(OH)_2$ in the sample has been converted into $BaSO_4$, the calculation is:

   231.75 parts : 170.16 parts : : 1.6 Gm. : wt. of $Ba(OH)_2$ in sample.

   Then weight of sample (1.2 Gm.) : wt. of $Ba(OH)_2$ in sample   : :   100% x.

   N. B.—Use the general rules for stating proportions.

48.   .6 Gm. of a certain iron ore is dissolved in HCl, oxidized to ferric iron with HNO_3, precipitated as ferric hydroxide, ignited to ferric oxide, yielding of the latter .52 Gm.   What % of iron in the ore?

Solution :   All the iron in the sample (.6 Gm.) is found in the ignited precipitate, existing in the latter as Fe_2O_3.   If we find the amount of iron (Fe) in the .52 Gm. of Fe_2O_3, we have therefore also the amount in the .6 Gm. of ore.

Mol. wt. Fe_2O_3 :   mol. wt. Fe_2 : :   .52 Gm. :   x (Fe in precip.)

.6 Gm.   : x   : :   100 % : y. (% of Fe in ore).

REDUCING VOLUMES OF GASES TO WEIGHTS AND VICE VERSA.

It has been determined that at normal pressure and temperature, 22.39 L. of any gas, without exception, will weigh the molecular weight of the gas expressed in Grammes*. Thus,

22.39 L. of H   weigh   2   Gm.   ⎫
22.39 L. of O   weigh 31.76 Gm.   ⎬ 2 atoms in the
22.39 L. of N   weigh 27.86 Gm.   ⎭   molecule.
22.39 L. of CO_2 weigh 43.66 Gm.
22.39 L of NH_3 weigh 16.93 Gm.
                etc.

This constant is of practical importance, as by its use the weight of any volume of any gas—or the volume of any weight—may be calculated by proportion.

As the weights and volumes are *directly* proportional —4 Gm. of H measuring twice as much as 2 Gm.—the general proportion for the determination of weight from volume would be:

22.39 L. : observed vol. in L. : : mol. wt. of gas in Gm. : x.   x = wt. in Gm. of observed volume.

And the general proportion for the calculation of the volume of a definite weight of any gas would be:
mol. wt. of gas in Gm. : observed wt. in Gm. : : 22.39 L : x
                              x = vol. of gas in L.

The general rule for the statement of the proportion may be used, as in the following examples.

1. What is the volume of 500 Gm. of oxygen?
Solution.—Mol. wt. of O = 15.88 × 2 = 31.76.

---

*Upon this observed fact is based Avogadro's hypothesis: All gases and vapors, without exception, contain, in the same volume, the same number of molecules.

Then the three known terms for the proportion are:
31.76 Gm., 500 Gm. and 22.39 L.

The answer is to express volume. Hence—

$$: \qquad :: \ 22.39 \ : \ x$$

The values being directly proportional, and the weight for which the volume is to be found being *larger* than the weight for which the volume is known [the molecular weight, expressed in Gm.] the answer will be *larger* than the third term. Hence—

31.76 Gm. : 500 Gm. : : 22.39 L. x (352.487 L.)

2. What is the weight of 50 L. of NH_3?

Solution.—Mol. weight of NH_3 = 16.93.

Then the three known terms are— 16.93 Gm., 50 L., and 22.39 L.

The answer is to express weight. Hence—

$$: \qquad :: \ 16.93 \ \text{Gm.} \ : \ x$$

The answer is to be larger than the third term. Hence—

22.39 L. : 50 L. : : 16.93 Gm : (37.8 Gm.)

Problems.

3. What is the volume of 1 Kg. of O? of 50 Gm. of CO_2? of 30 Gm. of H_2S? of 5 Gm. of Cl?

4. What is the weight of 50 L. of SO_2? of 10 L. of N_2O (laughing gas)? of 1 gallon of O? of 300 c.c. of H?

Note.—Oxygen, chlorine, and hydrogen have two atoms in the molecule; hence the molecular weight is, for each of these elements, double the atomic weight.

Effect of Variation in Pressure on the Volume of a Gas.

When the pressure upon a gas is increased, the volume of the gas is found to decrease correspondingly. If the pressure is doubled, the volume of the gas is thereby reduced to one-half the initial volume; if the pressure is tripled, the volume of the gas is reduced to one-third; if

the pressure is reduced to one-half the initial pressure
the volume of the gas becomes twice the initial volume;
etc.

Boyle's Law.—The relation of pressure to volume is
stated by Boyle as follows: With the temperature con-
stant, the volume of any given weight of any gas varies
inversely as the pressure upon it.

It follows then that if the volume has been observed
at any given pressure, the volume which the gas would
occupy at any other pressure may be calculated by pro-
portion.

5. The NO gas, evolved from a certain amount of
ethyl nitrite, measures 60 c.c. at a pressure of 744 mm.*
How much would it measure at 760 mm?

Solution.—Volume is asked for. Hence—

:   : :   60 c.c.   :   x

The values being inversely proportional, the NO
would measure *less* at 760 mm. than at 744 mm. The an-
swer is therefore to be *smaller* than the third term.
Hence—

760 mm.   :   744 mm.   : :   60 c.c.   :   x (58.73 c.c.)

Problems.

6. A Liter of ammonia gas at normal pressure,
would measure how much at a pressure of two atmos-
pheres? Ans. .5 L.

7. A quantity of CO_2, which measures 84.5 c.c. at
751 mm., will measure how much at normal pressure?

8. A quantity of O, measuring 3 gallons at 760 mm.,
would measure how much at 1.520 M? Ans. 1½ gal.

9. What would be the volume of 3 Gm. of SO_2 at
748 mm.

Note.—Remember that the constant, 22.39 L., is correct for
normal pressure only.

10.   What is the weight of 500 c.c. of Cl, measured at a barometric pressure of 752 mm. Ans. 1.554 Gm.

Note.—When a gas is collected over a liquid, as N_2O over water, the pressure of the gas is equal to the atmospheric pressure—i. e., barometric pressure.

Effect of Variation in Temperature on the Volume of a Gas.

The standard temperature for measuring gases is $0°C$. If the volume is taken at a different temperature [for sake of convenience], the volume at $0°C$. must be calculated from the observed volume before the constant, 22.39 L., can be made use of.

With the pressure remaining unchanged, the volume of a gas varies directly as its absolute temperature.*

By absolute temperature is meant temperature reckoned from $273°C$. below $0°C$. In other words, the zero of absolute temperature is minus $273°$, or $-273°C$. It follows then that temperature in $°C$. may be reduced to absolute temperature by adding $273°$† Thus, $15°C$. is $273 + 15 = 288°C$. absolute temperature; and $100°C$. is $273 + 100 = 373°C$ absolute temperature.

11.   A pharmacist in assaying spt. of nitrous ether has obtained a volume of NO gas measuring 56 c.c. at a temperature of $22°C$. What is the volume of the gas at $0°C$.?

Solution.— $22°C = 273 + 22 = 295°C$. abs. temp.
$0°C. = 273 + 0 = 273°C$. abs. temp.

The three known terms are: $295°C$ [absolute temperature at which volume was observed], $273°C$ [absolute temperature at which volume is wanted], and 56 c.c. [observed volume.]

The answer is to express volume.   Hence—

:   : :   56 c.c.   :   x

As the volume varies *directly* with the temperature;

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*This "law" is not exactly true for all gases.
†For directions for adding a positive quantity to a negative quantity (for instance, $273°C$. to $-20°C$.), see chapter XI.

and as the temperature at which the volume is wanted is *lower* than the temperature at which the volume is known, the answer must be *smaller* than the third term. Hence—

    295°C   :   273°C :: 56 c.c. : x(51.8 c.c.)

    The general proportion would be:

    Absolute temperature at which volume was observed *is to* absolute temperature at which volume is wanted [273°C + 0°C. = 273°C.] *as* observed volume *is to* x.*

Problems.

    12. A quantity of CO_2 measures 35 c.c. at 20°C. What will it measure at 0°C.? Ans. 32.6 c.c.

    13. A quantity of hydrogen measures 5 L. at 23° C. What would be its volume at 0°C.? What at 50°C? What at 100°C.?

    14. A quantity of NO measures 60 c.c. at a pressure of 750 mm., and at a temperature of 20°C. What would be its volume at normal pressure and temperature.

    Solution.— 760 mm. : 750 mm. :: 60 c.c. : x
x = 58.68 c.c. = vol. at norm. pressure.
Then 273 + 20°C. : 273 + 0°C :: 58.68 c.c. : x
x = 54.67 c.c. = vol. at norm. pressure and temp.

    15. What is the *weight* in Gm. of 60 c.c. of NO gas, measured at a barometric pressure of 750 mm., and at a temperature of 20°C.?

    Solution.—Having found the volume of the gas at normal pressure and temperature, as shown in the preceding example, we calculate the *weight* of that volume [in this case, 54.67c.c.] of NO thus:
22.39 L. : .05467 L. :: 29.81 Gm. [mol. wt. of NO]
: x.   x = .0729 Gm.

    16. How much $C_2H_5NO_2$ [ethyl nitrite] is indicated by 60 c.c. of NO at a pressure of 75 mm., and at a temperature of 20°C.?

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*It will be seen that a gas at 0°C. expands $\frac{1}{273}$ of its volume for an increase in temperature of 1°C.; and that it contracts $\frac{1}{273}$ of its volume for a decrease in temperature of 1°C.; in short, that the coefficient of expansion of any gas is $\frac{1}{273}$, or, decimally, .003665.

Solution.—Having calculated the *weight* of the NO, we calculate the amount of $C_2H_5NO_2$ required to produce the weight [in this case, .0729 Gm.] of NO gas.

Equation:

$$C_2H_5NO_2 + KI + H_2SO_4 = NO + C_2H_5OH + KHSO_4 + I.$$

   sought   *given*

   74.49   29.81
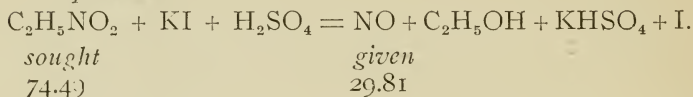
Then—

29.81 parts : 74.49 parts :: .0729 Gm. : x (.182 Gm.)

17. How many c.c. of CO_2, at normal pressure, and at a temp. of 25°C., would be generated from .5 Gm. of $NaHCO_3$?

Equation: $2NaHCO_3 + H_2SO_4 = Na_2SO_4 + 2CO_2 + 2H_2O.$
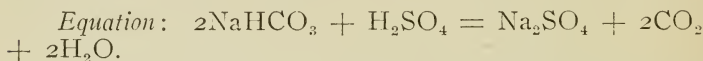
18. How many L. of hydrogen [pressure, 748 mm., temp., 20°C.] could be made from 5 Gm. of zinc?

19. How much $KClO_3$ is required to generate 25 L. of O.?

Equation: $2KClO_3 = 2KCl + 3O_2.$
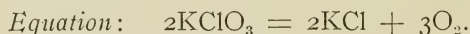
Note.—If pressure and temperature are not given, normal pressure and temperature are understood.

20. How much NH_4NO_3 is required to make 10 gallons of N_2O [laughing gas]?

Equation: $NH_4NO_3 = N_2 + 2H_2O.$

21. How much NH_4NO_3 is required to make enough N_2O to fill a 10 gallon tank, the temperature being 20°C., and the barometric pressure, 750 mm.?

For equation see prob. 20.

22. A certain quantity of baking powder yielded 70 c.c. of CO_2;—temp., 20°C., pressure, 748 mm. How much $NaHCO_3$ did the quantity of baking powder contain? Ans. 24 Gm.

Equation: $NaHCO_3 + acid = CO_2$ etc.
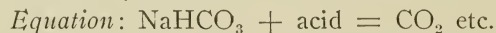
24. How many c.c. of ammonia water, sp. gr. .96, strength, 10%, would contain 5L. of NH_3 gas?

CHAPTER XI.

THERMOMETER SCALES.

On a Centigrade thermometer the temperature of melting ice [freezing point of water] is zero; and the temperature of steam, at normal pressure [boiling point of water], is 100.

On a Fahrenheit thermometer the temperature of

CENTIGRADE   FAHRENHEIT   REAUMUR
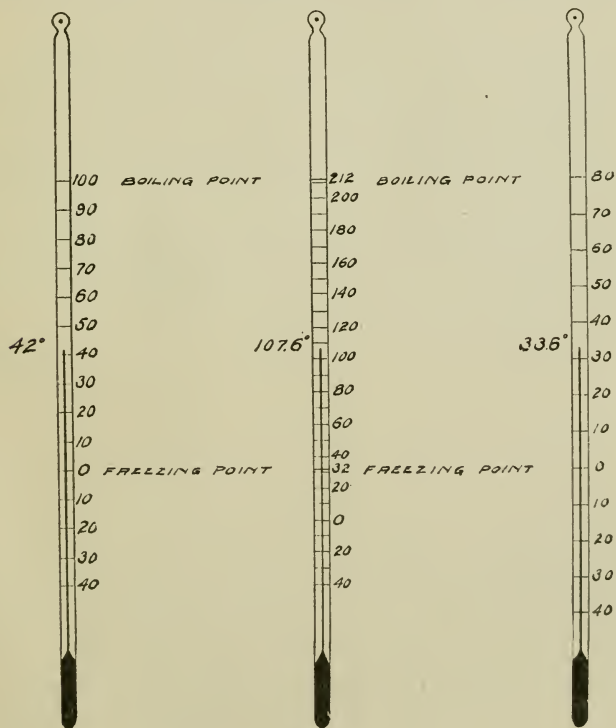
melting ice is 32 above zero; and the temperature of steam, at normal pressure, is 212.

On a Reaumur thermometer the temperature of melting ice is zero; and that of steam, at normal pressure, is 80.

On all three thermometers the graduation is continued above the boiling point, and below the zero point.

Temperature in degrees below zero, on any scale, is expressed as a negative quantity, the minus sign being placed before the number thus, —45°, which means 45° below zero. If the minus sign is absent, the number is *understood* to be a positive number, and to denote degrees above zero.

Centigrade to Fahrenheit.

It will be seen that 100°C = 180°F. = 80°R.; and hence that 1°C. = 1.8°F = .8°R.

Problem.—Convert 60°C. into °F.

Solution.—Since 1°C. = 1.8°F., 60°C = 60° × 1.8 = 108°F. But since 60°C. means 60° above the freezing point, the 108°F. must be counted from that same point; and as the freezing point is marked 32 on the F. scale, 32 must be added to 108 in order to get the reading counting from zero F. Accordingly, 108° + 32° = 140°; and 60°C. = 140°F. Whence the rule—

$$(°C. \times 1.8) + 32 = °F.$$

Problem.—Convert —25°C. into °F.

Solution.— —25 × 1.8 = —45 [Remember that when a negative quantity is multiplied by a positive quantity, the product is a negative quantity.] It will thus be seen that 25 divisions on the C. scale equal 45 on the F. scale. But since the freezing point on the F. scale is 32° above zero, and since the °C. are counted from the freezing point, the temperature of —25°C. would be —45° + 32; *which means that the reading would be 32° higher on the F. scale than* —45°, hence would be [—45 + 32] —13°F.

The rule for adding a positive quantity to a negative

quantity is as follows: Subtract the smaller number from the larger, and read the remainder with the sign of the larger number. Thus, —10 + (+ 32) = + 22; —42 + (+ 32) = —10.

Problem.—Convert —10°C. into °F.

Solution.— —10° × 1.8 = —18°.

And —18 + (+32) = +14. Hence —10°C = 14°F.

Note.—To add 32 means that the reading is to be 32° higher on the scale.

Fahrenheit to Centigrade.

Problem.—Convert 60°F. into °C.

Solution.—The first step to be taken is to find what would be the reading on the Fahr. thermometer if the freezing point were zero. This reading would be 32° lower than 60°, for zero on the Fahr. thermometer is 32° below the freezing point. Accordingly, we subtract 32° from 60°.

We have now ascertained that the temperature of 60° F. equals 28° assuming the zero point to be where it is on the Centigrade thermometer, namely at the freezing point.

Now 1°C. = 1.8° F.; then 28° F. must equal as many degrees C. as 1.8 is contained in 28°. Accordingly, we divide 28° by 1.8:

$$28° \div 1.8 = 15.5° \text{ C.}$$

Whence the rule—

$$(°F. —32) \div 1.8 = °C.$$

Problem.—Convert 10° F. into °C.

Solution.—If the zero on the Fahr. thermometer were at the freezing point [where it is on the Cent. thermometer], the reading would be 32° lower than 10°, hence would be —22°.

Then   —22° ÷ 1.8 = —12.2°C. (Ans.)

Problem.—Convert—10°F. into °C.

Solution.—If the zero on the Fahr. thermometer were at the freezing point [as in the Cent. scale], the reading would be 32° lower on the scale than —10°, hence would be —42°.

Then   —42° ÷ 1.8 = 23.3° C.

Note.—It will be seen that (+32) is subtracted from a positive quantity [from an above zero reading] smaller than 32 by finding the difference between that positive quantity and 32; that difference being a negative quantity, i. e., a reading beyond [below] the zero point.

And that (+32) is subtracted from a negative quantity [from a below zero reading] by adding 32 to the negative quantity, and calling the sum a negative quantity.

In short, **to subtract 32 means to find the reading 32° lower on the scale.**

CENTIGRADE AND REAUMUR.*

Problem.—Convert 15°C. into °R.

Solution.— 100° C. = 80° R. Then 1°C. = .8° R. And 15°C. = 15 × .8 = 12° R.

Whence the rule—   °C. × .8 = °R.

Problem.—Convert 15° R. into °C.

Solution.—Since .8°R.=1.°C.,15°R.=15°÷.8=18.7°C.

Whence the rule—   °R. ÷ .8 = °C.

FAHRENHEIT AND REAUMUR.

Problem.—Convert 60°R. into °F.

Solution.—Since 80°R. = 180° F., 1°R. = 2.25° F.

And 60° R. = 60 × 2.25 = 135°F. But since the zero of the R. scale is at the freezing point, the 135°F. must be counted from the same point. Hence 135° + 32° = 167°F.

Whence the rule—   (°R. × 2.25) + 32 = °F.

Problem.—Convert 61°F. into °R.

*The Reaumur scale is not used in the United States, and is of interest only because temperature is expressed in °R. in some European publicatitons.

Solution.– 61°F. = 61 — 32 = 29°F. above the freez-
ing point.   Then   29° ÷ 2.25 = 12.2°R.

Whence the rule   (°F.—32) ÷ 2.25 = °R.

Problems.

1. Convert (a.) 25°C. into °F.; (b.) 80°C. into °F.
2. (a.) 5°C into °F.; (b.) —5°C. into °F.
3. (a.) —30°C. into °F.; (b.) 2.5°C. into °F.
4. (a.) —2.5°C. into °F.; (b.) 1.1°C. into °F.
5. (a.) 125°F. into °C.; (b.) 25°F. into °C.
6. (a.) 5°F. into °C.; (b.) 5.8°F. into °C.
7. (a.) —5°F. into °C.; (b.) —1.1°F. into °C.
8. (a.) —25°F. into °C.; (b.) 31° F. into °C.
9. (a.) 10°C. into °R. (b.) 10°R. into °C.
10. (a.) —10°C. into °R. (b.) 10°C. into °R.
11. (a.) —10°R. into °C. (b.) 1.1°R. into °C.
12. (a.) 25°F into °R. (b.) 25°R. into °F.
13. (a.)—25°F. into °R. (b.)—25°R. into °F

Answers.
1. (a.) 77°F.; (b.) 176°F. 2. (a.) 41°F.; (b.) 23°F.
3. (a.) —22°F.; (b.) 36.5°F. 4. (a.) 27.5°F.; (b.) 33.98°F.
5. (a.) 51.66°C. 6. (a.) —15°C. 7. (a.) —20.5°C. 8. (a.)
—31.6°C.

MISCELLANEOUS.

BEAUME HYDROMETER SCALES.

(a.) **For Liquids heavier than water.**

Rule: Subtract the observed degrees Beaume from 145, and divide the remainder into 145. The answer is the sp. gr.

$$\text{Sp. gr.} = 145 \div (145 - °B)$$

Problem.—A certain carboy of hydrochloric acid is marked 20° B. What is its sp. gr.?

Calculation.— $145 - 20 = 125$; $145 \div 125 = 1.16$ (sp. gr.)

(b.) **For liquids lighter than water.**

Rule: Add the observed degrees Beaume to 130, and divide the product into 140. The answer is the sp. gr.

$$\text{Sp. gr.} = 140 \div (130 + °B)$$

Problem.—Ammonia water, marked 26° B., has what sp. gr.?

Calculation.— $130 + 26 = 156$; $140 \div 156 = .8974$ sp. gr.

PROBLEMS.

1. Reduce to sp. gr. the following degrees B. on scale for liquids heavier than water:—(a.) 18°B.; (b.) 25°B.; (c.) 30°B.; (d.) 50°B.

2. Reduce to sp. gr. the following degrees B. on scale for liquids lighter than water;—(a.) 18°B.; (b.) 30°B.; (c.) 40°B.; (d.) 50°B.

ANSWERS.

1. (a.) 1.00; (b.) 1.2; (c.) 1.26
2. (a.) .946; (b.) .874

CALCULATING DOSES FOR CHILDREN.

The rule most generally employed is known as Dr. Young's Rule, and is as follows:

Multiply the adult dose by the fraction obtained by dividing the age of the child [in years] by its age plus 12.

Problem.—If the adult dose of the medicine is 5 gr., what is the dose for a child 4 years old?

Calculation— $4 \div (4 + 12) = \frac{4}{16} = \frac{1}{4}$.

Then 5 gr. $\times \frac{1}{4} = \frac{5}{4} = 1\frac{1}{4}$ gr.

Problem.—The adult dose of a certain medicine is $\frac{1}{8}$ gr. How much should be given to a child 2 years old?

Calculation.— $2 \div (2 + 12) = \frac{2}{14} = \frac{1}{7}$

Then $\frac{1}{8}$ gr. $\times \frac{1}{7} = \frac{1}{56}$ gr.

Note.—Children are very susceptible to narcotics, especially to opium; and of these medicines less than one-half the amount indicated by Young's Rule is usually given. Of cathartics, however, double the calculated dose is generally required.

REFERENCE TABLES.

VOLUME AND WEIGHT.*

A. **Volume to Weight.**
  1. Cubic Centimeters to Grammes.
     no. of c.c. given × sp. gr. = wt. in Gm.
  2. Fluid Ounces to Grains.
     (455.7 × sp. gr.) × no. of f ℥ given = wt. in gr.
  3. Minims to Grains.
     (.95 gr. × sp. gr.) × no. of ♏ given = wt. in gr.
  4. Cubic Centimeters to Grains.
     (no. of c.c. given × sp. gr.) × 15.432 = wt. in gr.
  5. Fluid Ounces to Grammes.
     (no. of f℥ given × 29.57) × sp. gr. = no. of Gm.

B. **Weight to Volume.**
  1. Grammes to Cubic Centimeters.
     (no. of Gm. given ÷ sp. gr. = vol. in c.c.
  2. Grains to Fluid Ounces.
     no. of gr. given ÷ (455.7 × sp. gr.) = vol. in f℥.
  3. Grains to Minims.
     no. of gr. given ÷ (.95 gr. × sp. gr.) = vol. in ♏.
  4. Grammes to Fluid Ounces
     (no. of Gm. given ÷ sp. gr.) ÷ 29.57 = vol. in f℥.
  5. Grains to Cubic Centimeters
     (no. of gr. given × .0648) ÷ sp. gr. = no. of c.c.

VALUES WHICH ARE PROPORTIONAL.

Quantity (in wt. or vol.) to money value
In weight-percentage : — % to weights, but not to volumes.
In volume-percentage : — % to volumes, but not to weights.
In $\frac{w}{v}$ solutions : — (a) gr. of constituent to ♏ of solution.
                               (b.) Gm. of constituent to c.c. of solution.
In concentration and dilution : — % inversely to wt. of solution.
In alligation problems : — Proportionate parts to weights.
In chemical problems : — atomic and molecular weights to actual
   weights.
In gasometric problems :
                 (a.) volumes to weights.
                 (b.) volume inversely to pressure.
                 (c.) volume directly to absolute temperature.
In figuring interest, profit and loss, discount, etc. : % to money
   value.

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*For discussion of rules see Chapter III.

Table of Atomic Weights

Element	Symbol	At. Wt. Based on H = 1	Approximate At. Wt.	Element	Symbol	At. Wt. Based on H = 1	Approximate At. Wt.
Aluminum	Al	26.9	27	Lead	Pb	205.35	205
Antimony	Sb	119.3	119	Lithium	Li	6.98	7
Arsenic	As	74.4	74	Magnesium	Mg	24.18	24
Barium	Ba	136.4	136	Manganese	Mn	54.6	55
Bismuth	Bi	206.9	207	Mercury	Hg	198.5	199
Boron	B	10.9	11	Molybdenum	Mo	95.3	53
Bromin	Br	79.36	79	Nickel	Ni	58.3	58
Cadmium	Cd	111.6	112	Nitrogen	N	13.93	14
Calcium	Ca	39.8	40	Oxygen	O	15.88	16
Carbon	C	11.91	12	Phosphorus	P	30.77	31
Chlorin	Cl	35.18	35	Platinum	Pt	193.3	193
Chromium	Cr	51.7	52	Potassium	K	38.86	39
Cobalt	Co	58.56	59	Silicon	Si	28.2	28
Copper	Cu	63.1	63	Silver	Ag	107.12	107
Fluorin	F	18.9	19	Sodium	Na	22.88	23
Gold	Au	195.7	196	Strontium	Sr	86.94	87
Hydrogen	H	1.000	1	Sulphur	S	31.83	32
Iodin	I	125.9	126	Tin	Sn	118.1	118
Iron	Fe	55.5	56	Zinc	Zn	64.9	65

Multiples of Atomic Weights

H	1	2	3	4	5	6	7	8	9
O	15.88	31.76	47.64	63.52	79.40	95.28	111.16	127.04	142.92
H_2O	17.88	35.76	53.64	71.52	89.40	107.28	125.16	143.04	160.92
C	11.91	23.82	35.73	47.64	59.55	71.46	83.37	95.28	107.19
N	13.93	27.86	41.79	55.72	69.65	83.58	97.51	111.44	125.37
Cl	35.18	70.36	105.54	140.72	175.90	211.08	246.26	281.44	316.62
Br	79.36	158.72	238.08	317.44	396.80	476.16	555.52	634.88	714.24
I	125.9	251.80	377.70	503.60	629.50	755.40	881.30	1007.20	1133.10
S	31.83	63.66	95.49	127.32	159.15	190.98	222.81	254.64	286.47
Na	22.88	45.76	68.64	91.52	114.40	137.28	160.16	183.04	205.92
K	38.86	77.72	116.58	155.44	194.30	233.16	272.02	310.88	349.74

Prof. Letters. Apr. 6th 1907.

Metre = 3ft 3⅜ in. = ~~Stand~~ Unit of ~~length~~

4°C distilled water = maximum density.

1 c.c. water at 4°C = 1 c.c. = 1 gram

1 gram is unit of weight.

1 c.c. = 1 gram = 15.437 gr or 15½

1000 c.c. = 1 litre = Unit of volume.
33 ℥ (fluid)

___

Avoir-du-pois = Having weight.

7000 gr = 1 lb.   7000 ÷ 16 = 437½ gr.
16 oz = 1 lb.
1 oz = 437½ grains.

Apothecaries. weight.
5760 gr = 1 lb.   5760 ÷ 12 = 480
12 ℥ = 1 lb.
1 ℥ = 480 grains   20 gr = 1 ℈
3 ℈ = 1 ℥
8 ℥ = 1 ℥.

1 f ℥ always use the f to indicate fluid drams or ounces.

1 f ℥ = 455. grains. = 100 % to 1 ℥.
    4.55 = " = 1 % to 1 ℥.
    4.55 × 5 = 22.75 gr. = 5 % . to 1 ℥.
4 ℥ = 22.75 × 4 = 91 gr. of 5 % solution in 4 ℥ bottle.

1. U.S.P. gives average dose only.
2. U.S.f = U.S. Formulary.
3. U.S.D = U.S. Dispensatory.

How to be sure of a dose in a prescription. as —

    Tr. aconite   1 f ℥
. Simp. Syr. q.s. ℥iv.

Dose one teaspoonful.

To be sure of amount of aconite in Each teaspoonful given.

$\frac{7}{3}\overline{IV} = 32$ ʒ doses.

U.S.P. gives av. dose of aconite 1½ ♏

$32 \times 1\frac{1}{2}$ ♏ = 48 ♏.

1 fʒ aconite = 60 ♏. too large.

If ~~doctor~~ knows he is over-
dosing he indicates to the
pharmacist — by drawing
a heavy line under 1fʒ
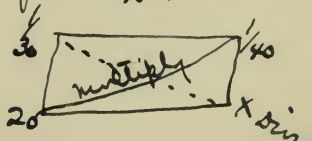

Metric weights and measures
are more accurate.

Conical graduates are in-
accurate ∀ ʒ̅ — a few drops
over 8ʒ would not be noticed.

1 ʒ̅ = 30 c.c.

Having

$\frac{1}{30} = \frac{2}{60}$ gr. strych. How give 1/40 g. dose

$\frac{1}{30} : \frac{1}{40} :: 20 : x(15)$ ♏.